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TRIPLE SHEET THERMOFORMING APPARATUS**[, METHODS AND ARTICLES]**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001.1] This application claims the benefits of U.S. Provisional Application No. 60/097,2000, filed August 20, 1998 and U.S. Patent Application No 09/377,792 filed August 20, 1999.

TECHNICAL FIELD

[0001] **[**The present inventions relate to thermoforming apparatus, methods and articles in general and, in particular, to thermoplastic articles constructed of three thermoplastic sheets formed by triple sheet thermoforming apparatus and methods.**]**

[0002.1] The present invention relates to thermoforming apparatus and, in particular, to a thermoforming machine for thermoforming three thermoplastic sheets over three thermoforming molds to produce an instant a unitary triple sheet article.

DESCRIPTION OF THE PRIOR ART

[0002] **[**The art of twin sheet thermoforming is well known and has been practiced extensively in recent years in the construction of plastic articles. The basic apparatus and principles of twin sheet thermoforming are well known and are provided by way of example in US Patents 3,583,036, 3,787,158 and 3,925,140 to Brown. The intended purpose of twin sheet thermoforming is to produce articles having greater strength than similar articles formed from a single sheet of thermoplastic.**]**

[0003.1] The art of twin sheet thermoforming is well known and has been practiced extensively in recent years in the construction of plastic articles. Twin sheet thermoforming has at least two intended purposes which include the production of hollow articles having greater strength than similar articles formed from a single sheet of

thermoplastic, and the consolidation of more than one thermoplastic sub-component into a single unitary article.

[0003] [Among articles thermoformed using the twin sheet methodology are plastic pallets which are constructed out of two thermoplastic sheets. An early example of a pallet formed in this general character is disclosed in US Patent 4,428,306 to Dresen et al.. Twin sheet pallets of the type referenced in US Class 108/53.3 are known in the field as nesting pallets.]

[0004.1] The apparatus of twin sheet thermoforming was pioneered by a handful of inventors in the late Sixties and early Seventies. A number of different types of twin sheet apparatus were developed and implemented during this period of time. Examples of these early types of twin sheet thermoforming apparatus may be known by referring to U.S. Patents 3,398,434 to Alesi, Jr., et al., 3,583,036 to Brown, 3,597,799 to Earle, 3,779,687 to Alesi, 3,783,078 to Brodhead, 3,787,158 and 3,867,088 to Brown et al..

[0004] [The art of twin sheet thermoforming extends to yet another type of plastic pallet referred to as a racking pallet. A racking pallet is designed to support a load between the two parallel beams of warehouse storage racks. Examples of rackable plastic pallets are disclosed in US Patents 5,117,762 to Shuert, and 5,197,396 to Breezer et al. As is widely understood in the field, racking pallets formed by thermoforming methods and constructed out of high density polyethylene (HDPE) thermoplastics exhibit a high degree of creep, such that over time and under loaded conditions, the racking pallet deflects and eventually fails. Accordingly, it is common practice to reinforce racking pallets with rigid non-thermoplastic cross-members interposed between the twin sheets forming the structures of the pallet.]

[0005.1] The basic apparatus and principles of twin sheet thermoforming preferred by practitioners, as of the time of the present invention, are disclosed in U.S. Patents 3,868,209 to Howell and 3,925,140 to Brown. In fact, Brown Machine LLC, of Beaverton Michigan, is internationally renown as the premier manufacturer of twin sheet thermoforming machinery. Several other machinery manufacturers, domestic and foreign, offer twin sheet thermoforming apparatus based upon the principles of the '209 and '140 inventions in the rotary machine configuration. Although other twin sheet machine configurations are offered, such as linear machine configurations, the rotary style is much preferred for its inherent short cycle time.

[0005] [Twin sheet thermoplastic pallets of the nesting and racking variety have been employed with some degree of success. The problems associated with traditional pallets formed

of wood have been largely overcome with the use of thermoplastic pallets formed by thermoforming methods. There are problems however associated with twin sheet thermoformed plastic pallets. A common problem with twin sheet nesting pallets is that a network of stiffening recesses are molded into the top surface to increase flexural strength as well as to provide fusion points connecting the top sheet to the underlying sheet of the molded plastic pallet. Recesses are disadvantageous because they reduce the surface area available for supporting loads upon the pallet. Recesses also capture debris and liquid that may damage or contaminate goods transported upon the surface of the pallet. Another common problem with many twin sheet pallets is that they are not easily recycled because they contain rigid non-plastic cross-members, or equivalent structures, which are used to add strength. These rigid non-plastic structures have to be removed and separated before the thermoplastic used to construct the pallet can be recycled and reused. Another problem with twin sheet racking pallets of the type disclosed in the prior art is that mechanical fasteners are required in practice to join and maintain an upper load bearing pallet structure to a lower load supporting pallet structure in spaced parallel relation. Mechanical fasteners are costly and require special care and attention to both maintain the working life of the plastic pallet and to provide for the recycling and reuse of the thermoplastic used to form the pallet. The double deck plastic pallet disclosed in US Patent 5,197,396 to Penda Corporation is hereby provided as an example to describe the problems characteristic of twin sheet pallets.]

[0006.1] A wide variety of small and large articles thermoformed according to the twin sheet methodology are found in a large number of primary end markets including recreational and sporting goods, building and construction, automotive and transportation, marine, agricultural, appliance, industrial and consumer products to name a few. However, the largest end-market application to which twin sheet thermoforming apparatus has been widely applied involves industrial platforms such material handling pallets and the like.

[0006] [A considerable number of proposals have been offered by Shuert in US Patents 5,404,829, 5,391,251, 5,255,613, Continuations-in-part of Ser. No. 993,762, Dec. 18, 1992, Pat. No 5,401,347, and Continuation-in-part of Ser. No. 636,062, Apr. 22, 1996, Pat. No. 5,676,064, to over come problems associated with twin sheet pallets and in particular with mechanical fasteners. In summary, Shuert proposes "fusion" as a means of joining the various pallet structures referenced in the detailed descriptions of his pallet inventions. However, [after careful analysis of the specifications made in the aforementioned patent material,] Shuert does not teach how a plurality of separate thermoplastic pallet structures can be fused together in substitution of mechanical fasteners. [Disclosures and claims of this nature and scope are akin to claiming commercial production of gem quality diamonds through the application of energy upon an admixture of aggregate.] Thus, Shuert does not adequately disclose how two or more twin and

single sheet components can be fused together to produce a resilient and durable stacking pallet structure.]

[0007.1] The traditional wood pallet is an integral part of America's distribution system, and is involved in one way or another in the movement and storage of the vast majority of goods within the economy. Wood pallets however have a large number of problems that well known and plastic pallets have been used to some advantage in recent years. While plastic pallets are attractive for a number of known reasons, they still have two significant shortcomings. Most notably, plastic pallets deform under heavy load and unless reinforced with steel, wood or the like, do not provide acceptable strength. Secondly, plastic materials are more expensive than wood materials and a relatively large amount of plastic is used to make a pallet comparable in strength to wood. Therefore, plastic pallets are considerably more expensive than wooden pallets.

[0007] [The traditional 48 inch x 40 inch "GMA" wood pallet remains an integral part of America's grocery distribution system today, and is involved in one way or another in the movement of over 90% of all dry goods. It is estimated that the current inventory of wood pallets costs the grocery industry nearly $2 billion annually, almost half of which is determined to be the result of product damage, carrier inefficiencies, productivity losses, and time allocated to sort and repair wood pallets. Although twin sheet thermoformed pallets of the type characteristic in the prior art have been used to some advantage in recent years, they do not yet comply with the set of standard pallet-design specifications that would reduce the costs associated with pallet exchange systems used within the grocery industry. While thermoformed plastic pallets are attractive for durability and ease of sanitation, they still have several shortcomings. Most notably, current thermoformed pallets deform under heavy load and unless reinforced with steel, wood or the like, do not provide acceptable racking strength. Conventionally reinforced thermoformed pallets are therefore costly and less susceptible to recycling. Accordingly, the art must be advanced significantly before thermoformed plastic pallets will enjoy wide acceptance within the many sectors of the material handling industry.]

[0008.1] One to the most successful types of plastic pallets is a twin sheet thermoformed pallet. Twin sheet pallets are generally constructed out of two thermoplastic sheets according to the principles and apparatus of '140. An early example of a pallet formed in this general character is disclosed in U.S. Patent 4,428,306 to Dresen et al. The two significant shortcomings associated with plastic pallets are not, however, overcome with twin sheet thermoforming.

[0008] **[**Another application of twin sheet thermoforming is found in the area of thermoplastic dumpster lids. Double walled thermoplastic dumpster lids produced by the twin sheet thermoforming method have been used to replace metal dumpster lids with some success. Thermoplastic dumpster lids have the advantages of being low cost, light weight, quiet, rust proof and relatively dent resistant. Thermoplastic dumpster lids thermoformed of PE materials however have some problems. PE twin sheet dumpster lids undergo significant wear, <u>and</u> tear and abuse during regular use. Opening and closing the lid over an extended period of time causes hinge points formed in the dumpster lid to weaken and develop stress cracks which radiate into the main body of the lid, thus causing failure and in some cases danger to children playing upon the dumpster. Therefore, the art still requires further advancement to overcome strength related problems.**]**

[0009.1] <u>Phil Araman of the United States Forest Service has estimated that there are 1.9 billion pallets within the U.S. distribution system, and that roughly 400 million new pallets are added to maintain the over-all inventory each year. Of this annual volume, twin sheet thermoformed pallets reportedly only account for roughly 1.4 million units. Therefore, the practitioners of twin sheet thermoforming have attempted in recent years to improve the art of twin sheet thermoforming to overcome the significant shortcomings noted above in order to capture a larger share of the over-all pallet market. Some of the more notable apparatus improvements may be known by referring to U.S. Patents 5,620,715 to Hart et al., 5,800,846 to Hart, 5,975,879 and 6,086,354 to Dresen et al., and 5,658,523 and 5,843,366 to Shuert. Upon close inspection of these improvements, it will become readily apparent that the significant shortcomings have not yet been overcome in the prior art. The improved apparatus referenced has only provided incremental improvement results and the basic apparatus still yields twin sheet pallets that have relatively low load bearing strength and remain expensive compared to wooden pallets.</u>

[0009] **[**Many other small and large articles thermoformed according to the twin sheet methodology are found in a wide variety of primary end markets including recreational and sporting goods, building and construction, automotive and transportation, marine, agricultural, appliance, industrial and consumer products to name a few. Substantially all articles thermoformed according to the twin sheet methodology have either greater strength than similar articles formed from a single sheet of thermoplastic; they provide greater cost efficiencies in the manner in which they are produced and reinforced to replace an existing product of the similar application; or, they offer improved quality as a result of parts consolidation and ease of manufacture.**]**

[0010.1] Although the art of twin sheet thermoforming has resulted in improved products in a wide variety of applications and end markets, a range of needs nonetheless exists to advance thermoforming methods and apparatus to overcome such specific weaknesses as have been mentioned above, and more generally, to further increase the strength, lower the costs or improve the quality of articles constructed of thermoplastic materials.

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[0011.1] It has been suggested that three or more sheets of thermoplastic can be combined in a form analogous to a honeycomb construction in order to overcome a wide range of strength related problems, cost issues and to achieve parts consolidation benefits. Continuing with the present example of plastic pallets, in U.S. Patent 5,470,641 a routine twin sheet panel structure is over and/or under laid with separate (coextensive) sheets in separate forging like operations to provide a panel structure with one or more flat face plates. In yet another example, which is understood best by referring to U.S. Patent 4,348,442, a structural panel substantially equivalent to the panel structure of '641 is disclosed. There are a number of problems that would be readily apparent to those skilled in the pertinent arts with respect to the end products associated with these disclosures. First, it will be appreciated by referring to U.S. Patent 3,919,446 that the twin sheet structure of '641, in particular, would be more economically achieved by the single sheet expansion process of '446. Secondly, the perimeter borders of '641 and '442 are normally open and could collect or retain contaminants associated within material handling environments. Third, the secondary operations of fusing, screwing and bonding the separate thermoplastic sub-components together would be difficult and costly to implement. Fourth, except as may be anticipated by '442, the approach of '641 is not amenable for use as a pallet structure in which legs are required for the receipt of pallet handling equipment and machinery. Fifth, as is well know, and as first taught by U.S. Patent 4,428,306, single walled thermoplastic legs are not strong enough to support the tremendous static loads required by industry. Sixth, it is critical to provide a wide spread and permanent interfacial connection between all of the mating surfaces of the

thermoplastic sub-components forming the referenced hybrid honeycomb panel structures in order to achieve maximum load bearing and anti-delaminating strength. The assembly methods inferred and or suggested by '641 and '442 would not be amenable to such wide spread and permanent interfacial unions, with the result that the articles would not be optimally robust. Seventh, the introduction of aggregates, fillers, agents, adhesives, fasteners and other non-thermoplastic joinery would create problems with respect to the recycling of the reference multi-sheet panel structures at the end of their useful lives.

[0012.1] Therefore, although triple, even quadruple sheet thermoplastic constructions would enjoy the theoretical strength advantages associated with honeycomb sandwich constructions, the art of thermoforming has not yet been advanced to a point where at least three thermoplastic sheets could be instantly thermoformed over three shape-giving molds to provide unitary articles that overcome the problems that by way of example have now been identified.

SUMMARY OF THE INVENTION[S]

[0011] [These inventions are directed toward advancements in thermoforming apparatus and methods and thermoformed articles. More specifically, these original inventions propose the innovations of triple sheet thermoforming apparatus and methods to produce novel triple sheet articles that overcome twin sheet product weaknesses, or in articles that achieve unique objectives and provide original advantages.]

[0013.1] It is, therefore, the objective of the present invention to provide a machine for thermoforming three sheets of thermoplastic over three molds to provide, in an instant manufacturing process, a unitary triple sheet thermoplastic article.

[0012] [This specification therefore summarizes three fields of invention. A first field of invention describes the apparatus of triple sheet thermoforming machinery. A second field of invention describes the methods of triple sheet thermoforming. A third field of invention describes four articles that may be made according to the apparatus and the methods of triple sheet thermoforming.]

[0014.1] Accordingly, an object of the present invention is to provide a machine having three ovens within which three sheets of thermoplastic can be simultaneously heated to a thermoformable state. The object is accomplished by providing three ovens

comprising five oven banks, with the first oven bank uniquely positioned at the load/unload station above the wheel supporting the clamp frames that hold the individual sheets forming a triple sheet article. Although the fifth oven in the present embodiment is positioned over the load/unload station characteristic of a four-station rotary machine, this aspect can be accomplished in a five or six station rotary configuration.

[THE APPARATUS OF TRIPLE SHEET THERMOFORMING]

[0013] [The first invention generally relates to twin sheet thermoforming machinery and in particular to apparatus that advances the art from twin to triple sheet thermoforming.]

[0015.1] According to a further aspect of this object, the three ovens comprising the five oven banks each include a plurality of infrared emitters. As each of the three sheets progress through each of the three ovens means regulating emitter output are precisely controlled to ensure that the over-all amount of heat transferred to each of the three sheets is controllable and therefore adjustable according to the length of time each of the three sheets dwells in each of the three ovens. According to this aspect, each emitter of each oven bank is controlled to emit more or less heat energy relative the heat absorption characteristics of the individual sheets of thermoplastic and the varying length of time each sheet dwells within each of three ovens.

[0014] [As is well known in the art twin sheet thermoforming, twin sheet thermoforming machinery includes four workstations and a wheel with four clamp frames. The wheel rotates about an axis located centrally, with the four stations located in four quadrants equivalent to the 12 o'clock, 3 o'clock, 6 o'clock and 9 o'clock positions. The wheel is likewise configured into four quadrants such that the four frames of the wheel register vertically in spaced parallel relation with the four station quadrants. Station 1, generally at the 6 o'clock position, in a twin sheet thermoforming machine, is arranged to load sheet into the four frames and to remove twin sheet articles from the second and fourth of four frames. Station 2, generally at the 9 o'clock position, includes a first upper and a first lower pre-heat bank of infrared emitters, which heat a sheet 1 loaded into the frame 1 of the wheel. Station 3, generally at the 12 o'clock position, includes a second upper and lower bank of infrared emitters, which continue to heat sheet 1 as the wheel is indexed forward carrying sheet 2 loaded into the frame 2 from station 1 to station 2. Station 4, generally at the 3 o'clock position, includes first lower and second upper platens holding a first lower mold and a second upper mold. Sheet 4 is loaded into frame 4, sheet 3 is indexed forward to station 2, sheet 2 to station 3, sheet 1 to station 4, where lower platen extends upward and heated

sheet 1 is thermoformed by known manner over the lower mold held upon the lower platen. After sheet 1 is thermoformed over the lower mold, frame 1 opens from the bottom and releases sheet 1, and the lower platen retracts with sheet 1 held under vacuum over the lower mold. The wheel indexes forward carrying sheet 2 to station 4, sheet 3 to station 3 and sheet 4 to station 2. While a sheet 5 is loaded into station 1, the upper platen of station 4 extends downward and sheet 2 is thermoformed over a second upper mold by known manner. After sheet 2 is thermoformed over second upper mold, and while second upper platen is maintained in an extended position at the sheet line, the lower platen extends upward carrying thermoformed sheet 1 upon first lower mold to sheet 2 upon second upper mold. When both platens are extended they are interlocked in known manner and sheets 1 and 2 are selectively fused together at predetermined knitting points as the lower mold and the upper mold are compressed by the further upward extension of first lower platen. After heated thermoformed sheets 1 and 2 have been fused together in known manner, the lower and upper platens and molds retract leaving the twin sheet article in frame 2. After a period of delay, during which time the twin sheet article is cooled by means well understood, and sheets 3 and 4 are heated to thermoforming temperatures, the wheel is indexed forward. The first twin sheet article is then unloaded at station 1, and a sheet 6 is loaded into frame 2 at station 1. Sheet 5 is indexed to station 2, sheet 4 is indexed to station 3, and sheet 3 is indexed to station 4, wherein the twin sheet thermoforming process is repeated in continuous phase.]

[0016.1] Still according to this aspect, the invention includes means adjusting the vertical position of the first oven bank relative the wheel supporting the clamp frames carrying the plastic sheets in order to prevent triple sheet articles from impacting the first oven bank as the article is indexed forward from a from station to the load/unload station.

[0015] [Accordingly, an object of the present invention is to increase the heating capacity of a thermoforming machine by providing for the heating of three successive sheets. The object is accomplished with unique arrangement of a third heater station upon a four station thermoforming machine. Apparatus including a fifth bank of infrared emitters is uniquely provided at the load/unload station above the wheel so that in the novel triple sheet thermoforming machine three thermoplastic sheets can be successively loaded into the machine and heated within three ovens.]

[0017.1] Another object of the invention is to provide means controlling the operation of the clamp frames. According to this aspect, means are provided for a three sheet sequence in which case programmable logic control is required to ensure the clamp frames respond to proper open or close operating functions at the form station.

[0016] [Another object of the invention is to provide five heater banks that can be selectively calibrated and controlled according to the heat absorption characteristics of the thermoplastic sheet specified for the triple sheet article. Therefore, a unique feature of the present invention is to provide heaters with controls suitable for triple sheet thermoforming. Heat can be transferred in three ways, namely conduction, convection or radiation. Infrared heat is one form of radiation that happens to best match the absorption characteristics of most thermoplastics. There are many options for radiating infrared heat. Some of the most common of these are electric heaters including calrods™, ceramic elements, panel heaters and quartz tubes. Quartz tubes are the industry standard when fast response is required. Quartz tube heaters can be quickly adjusted to match the requirements of different sheet thickness and oven duration times. Electric heaters used in the triple sheet thermoforming operations should provide at least 15 watts per square inch (wsi) on each of the top and bottom oven banks, for a minimum machine total of 75 wsi . To facilitate more responsive heating, ceramic elements can be spaced to provide 30 wsi, or quartz tubes with a maximum 60 wsi can be used for each of the 5 oven banks, for a total of 300 wsi. Power switching devices [devises] such as solid state relays or silicon controlled rectifiers are preferred and are controlled by either PLCs or computer bases systems so that emitter profile sequence recipes for all heaters can be adjusted and repeated in phase with triple sheet thermoforming processes. Additionally, infrared sensors are used to control heater temperatures where conditions warrant response to variation. Accordingly, it is an objective of the present invention to provide 3 top and 2 bottom heat sources having a minimum density of 15 wsi, and PLC controlled closed loop control systems facilitating multivariate oven zone and heater profile control from cycle to cycle.]

[0018.1] Still according to this aspect, pivotally opposed pin bars mounted to co-acting solenoid operated cylinders are suggested in order to enable various modes of the invention to be used. Pivotally opposed pin bars allow the formed sheets of thermoplastic at the form station to be extracted to a position above or below a sheet line associated with the path traveled by the wheel as preferred by the thermoforming practitioner.

[0017] [Another object of the invention are controls suitable for emitting higher or lower heat profiles from one frame carrying thicker sheet to a next frame carrying thinner sheet. Triple sheet thermoforming apparatus features [featurers] rapid response heaters and heater control so that the triple sheet article to be thermoformed according to the triple sheet methodology to be constructed out of different thermoplastic sheets and in combinations which optimize the strength to weight to cost ratios of the article being constructed.]

[0019.1] Another object of the invention is to provide means delivering three shape-giving molds that each separately thermoform one of the three sheets of thermoplastic of the unitary article. According to this aspect the machine has a form station comprising opposed platens that travel vertically from open positions to closed positions where the three sheets of thermoplastic are sequentially thermoformed over the three molds.

[0018] [Another object of the invention proposed herein is apparatus for moving the first upper bank of heaters from a position close to the sheet line to a position away from the sheet line. This novel object prevents articles rotating from the form station from crashing into elements of the heating apparatus above the wheel at the first load/unload station.]

[0020.1] According to this aspect the opposed platens are developed to support and carry three molds into positions relative for thermoforming. In this connection, associated with at least one platen is a mold shuttle system, the mold shuttle system providing means to laterally shift one of two molds into position upon the associated platen for vertical movement into positions relative for thermoforming.

[0019] [It is yet another object of the present invention to provide for the addition of a third thermoforming mold upon which a third thermoplastic sheet is molded to form a triple sheet article. This object is accomplished with a slide assembly upon which two molds are releasably secured. The slide assembly cooperates with the vertically movable upper platen and elements of it move laterally in a first direction to position a first upper mold into vertical alignment above a first sheet, and laterally in a second direction to position a second upper mold into vertical alignment above a third sheet. It will be seen in the detailed description of the present invention, that interposed between the molding of the first and third sheets is the molding of a second sheet upon a first lower mold found upon the lower vertically movable platen. The slide assembly is operated to facilitate a basic characteristic of the innovative triple sheet methodology.]

[0021.1] According still to this aspect, means are provided to control the open and closed positions of the platens relative for thermoforming three sheets over three molds and for operation of the mold shuttle system.

[0020] [Another object of the present invented apparatus is the provision of co-engaging, pivotally opposed pin bars mounted to co-acting solenoid operated cylinders that open from the top and the bottom. Twin sheet clamp frames open from the bottom. This arrangement is used so that a first sheet thermoformed over a mold mounted to the lower platen can be released from the first frame and lowered away from the sheet line where a second sheet traverses into the form station and is thermoformed over a second mold mounted upon the upper platen. In the triple sheet

methodology, it is necessary to extract at least one molded sheet away from and above the sheet line while another sheet is being molded upon a mold affixed to an opposed platen. Therefore, another [a] feature of the present invention is a novel clamp frame apparatus that opens from the top and the bottom to facilitate an unanticipated characteristic of triple sheet thermoforming.]

[0022.1] Yet another object of the invention is to sequentially compress the formed sheets of thermoplastic between the molds supported upon the platens to first provide a twin sheet sub-assembly and then a unitary triple sheet article. According to this aspect the platens are closed in a manner having the attributes of a forging operation. Means for implementing the forging-like operation first between a first set of molds and next between a second set of molds are provided.

[0021] [Another object of the invented triple sheet clamp frames is the manner in which they are controlled in the triple sheet thermoforming process. As is well understood in the twin sheet methodology, the single action solenoid operated cylinders open after the first sheet is molded and remain closed after the second sheet is molded. This sequence is repeated in phase in the twin sheet methodology, and requires relatively simple process control. The triple sheet methodology is substantially more complicated. In one preferred embodiment of the present invention, the first, second and third frames of the first complete part production cycle follow opened, opened and closed instructions, respectively. In the second part production cycle, the fourth, first and second frames respond to opened, opened and closed instructions. Following this logic, it is seen that all of the clamp frame assemblies of the present invention [ivented] thermoforming apparatus must be able to respond to either opened or closed instructions in phase with the triple sheet methodology proposed. Accordingly, another feature of the invention are novel triple sheet clamp frame controls that are provided to instruct the clamp apparatus to open or remain closed in phase with the triple sheet thermoforming process. Still yet another feature of the present invention [invented] apparatus is [are] means of platen control which is enabling retract and extend setting of the upper and lower platens to vary in vertical elevation according to the tooling and triple sheet methodology used to thermoform the triple sheet articles proposed. As is understood in the practice of twin sheet operations, upper and lower platen retract and extend positions are sequenced in phase according to the forming and fusing of two sheet members. This is a relatively simple matter. The requirements of the triple sheet thermoforming methodology are considerably more complicated. An apparatus is proposed herein [Apparatus] for vertically adjusting the upper and lower platen positions relative to each other and in phase with the forming of three thermoplastic sheets over three thermoforming molds [is proposed]. Accordingly, it will be seen that the apparatus disclosed includes means and controls that enable the platens to extend and retract to different vertical positions depending upon the relative distances that the molding

surfaces of the molds affixed to the slide structures residing upon the platens bear in relation and phase to the sheet line. An apparatus [Apparatus] and controls are required for the vertical adjustment of the platens in the triple sheet thermoforming methodology.]

[0023.1] According to still yet another object, a machine frame to support the equipment associated with the apparatus is disclosed in connection with a rotary machine configuration, although a liner machine frame falls within the scope of the invention.

[0022] [Still yet another feature of the present invention is that the triple sheet apparatus is generally amenable to being installed upon existing twin sheet machinery so that the art of triple sheet thermoforming can be practiced for advantage at a reasonably lower cost. A triple sheet retrofit apparatus kit can therefore be developed to convert a twin sheet machine into a triple sheet machine. The cost of a proposed retrofit kit would be substantially lower in terms of the economic and lead-time costs associated with the purchase of a new triple sheet machine. A triple sheet retrofit apparatus kit would provide the advantage of enabling practitioners of the twin sheet methodology to improve the articles they produce by advancing to the methods and apparatus attendant with the triple sheet thermoforming inventions disclosed herein.]

[0024.1] Other features, objects and advantages of the present invention apparatus will become apparent from the following description and appended claims when viewed in conjunction with the accompanying drawings.

[THE METHODS OF TRIPLE SHEET THERMOFORMING]

[0023] [The method of triple sheet thermoforming is advantageously accomplished by successively molding and fusing three sheets of thermoplastic material together to produce a single article. Triple sheet methods provide significant advantages over standard twin sheet methods. For example, in one embodiment of the method, a second molded sheet is interposed between a first molded sheet and a third molded sheet to provide the advantage of a more rigid article. In another embodiment of the method, a triple sheet article is produced providing two cavities within which two media may be stored. Accordingly, a significant feature of the present invention is the range of applications to which the novel methods of triple sheet thermoforming may be applied.]

[0024] [Characteristic of the sequences of the methods of triple sheet thermoforming are the following steps that occur at the fourth forming station. In Step I, a first sheet [1] is thermoformed upon a first mold [1] mounted to the upper platen, released from a first frame [1] and extracted above the sheet line while under vacuum. In Step II, a second sheet [2] is thermoformed upon a second mold [2] mounted to the lower platen, the first sheet [1] and mold [1]

are extended downward to be compressed against the second sheet [2] and mold [2], fused first and seond sheets [1 & 2] are then released from the second frame [2]. the first mold [1] ejects the first sheet [1] and retracts above the sheet line, and the fused first and second sheet sheets [1 & 2] are extracted below the sheet line with the second sheet [2] remaining upon the second mold [2] while under vacuum. In Step III. a third mold [3] mounted upon the upper platen slides laterally into position above a third sheet [3], the upper platen extends and the third sheet [3] is thermoformed upon the third mold [3], fused first and second sheets [1 & 2] and the second mold [2] are then extended upward and compressed against the third sheet [3] and the third mold [3]. the second mold [2] ejects the first and second fused sheets [1 & 2] while the third mold [3] ejects the third sheet [3], second and third molds [2 & 3] are the third retracted below and above the sheet line, and the triple sheets [1. 2 and 3] remain clamped in the third frame [3]. The triple sheet article is indexed forward and is removed at the load/unload station whereafter the sequences of triple sheet thermoforming are repeated in phase at the forming station.]

[0025] [In order to accomplish the method of triple sheet thermoforming it is necessary to provide three heating stations within which three thermoplastic sheets are successively heated to thermoformable temperatures. As will be understood in the detailed description of the present inventions. the dwell time of the three sheets [1. 2 and 3] at heating stations [1. 2 and 3] will be sufficient to bring the three sheets [1, 2 and 3] to the temperatures necessary to thermoform the triple sheet article. Such would not be the case if only the second and third heating stations [2 and 3] were provided. As will also be seen. in practicing the methods of triple sheet thermoforming it is proposed that heater output at the heating stations be adjustably variable for a range of purposes. These purposes include compensating for the heater output differences of]heat station 1 and] the three heat stations [2 and 3], and compensating for the heat absorption characteristics of up to three specialized thermoplastic sheets wherein one sheet may be filled to provide flexural strength, or others may not equal the average starting gauge of the thermoplastic used.]

[0026] [It is yet another feature of the present invented method to provide three molds against which three thermoplastic sheets are molded and fused together to produce a triple sheet article. The method is practiced with the provision of a slide assembly that holds two molds and is operable to release one mold at a time onto a platen that travels from an open position to a closed position whereat a sheet is thermoformed against a mold surface.]

[0027] [Another feature of the present invented method concerns the triple sheet clamp frames. As noted in the above reference to the characteristic steps of the method, the triple sheet clamp frames receive instructions to open or remain closed in phase while they dwell in the form station. The triple sheet method teaches the controlled operation of the open and closed functions of the triple sheet clamp frames.]

[0028] [Another feature of the triple sheet clamp frames is the method whereby the frames open from the top and the bottom. When a molded sheet is released from the frames so that it can be move out of the way for the next sheet to be molded, the molded sheet can not be obstructed by the invention as it travels away from the sheet line. Twin sheet clamp frames that open from the bottom would prevent a sheet held upon a mold mounted to the upper platen which has been released from the botton from traveling above the sheet line in order for a second sheet to be thermoformed upon a mold mounted to the lower platen.]

[0029] [Another feature of the present invented method is [are] means for inserting rigidizing structures within the triple sheet article to be thermoformed by the triple sheet methodology. In the sequence of thermoforming and fusing the triple sheet article referred to above, [it will taught that between Step 2 and Step 3] a structure to reinforce the article is [can be] placed upon a molded sheet, prior to its compression and selected fusion to another sheet, between Steps II and III . It will also be appreciated that in this manner, such structures as may be placed within the article will be fully encapsulated to provide a robust and durable reinforced triple sheet structure. As may also be understood, automated mechanical means may be employed to deliver a structure to reinforce the article from an inventory of such structures to the desired position and at the designated time to reinforce the triple sheet article to be thermoformed by the triple sheet methodology.]

[0030] [Other features of the present invention are the methods whereby three sheets are fused together to produce a triple sheet article. A range of fusing methods is proposed to facilitate the fusing together of three sheets of thermoplastic to produce a wide range of triple sheet articles. For example, one method describes how three sheets are fused in areas where there is no support or compression resistance. Another method describes how three sheets are fused without collapsing at least one of the three sheets as they are compressed between two platens.]

[ARTICLES PRODUCED BY TRIPLE SHEET THERMOFORMING]

[0031] [This invention is directed to articles that may be thermoformed by triple sheet apparatus and methods, and in particular to shipping pallets that are constructed for advantage out of three sheets of thermoplastic material.]

[0032] [In one embodiment of the present invention, a nesting pallet constructed out of three sheets of thermoplastic material is proposed. An objective of the nesting pallet is to provide a rigid thermoplastic member that is sandwiched between two outside thermoplastic pallet members. An advantage of this arrangement is that it provides a nesting pallet with superior flexural strength. Another object is to produce a nesting pallet that is devoid of a network of strengthening recesses

and fusing points which in combination reduce the load bearing surface area of the pallet. Another object of the present embodiment of the invention is to produce a pallet that is lightweight and 100% recyclable.]

[0033] [In another embodiment of the present invention, a load distributor constructed out of three sheets of thermoplastic material is proposed. An object of the load distributor is to provide a rigid thermoplastic member sandwiched between top and bottom members. An advantage of this arrangement is that it provides a load distributor with increased flexural stiffness. Another object is to provide a rigid thermoplastic member that provides compressive strength where the wheels of the pallet jack are introduced to move the load distributor. Another object of the present embodiment of the invention is to produce a load distributor that is lightweight, low in cost and is 100% recyclable.]

[0034] [In yet another embodiment of the present invention, a light-duty racking pallet constructed out of three sheets of thermoplastic material is proposed. An object of the light-duty racking pallet is to provide a load supporting deck structure that is permanently fused by means of the triple sheet method to a load distributing base structure. A significant advantage of this arrangement is that it eliminates the need to interpose a plurality of feet or legs of the type requiring mechanical fasteners between the upper and lower deck structures as is common in the art of racking pallets. Another object of the present invention is to eliminate mechanical fasteners. Other features of the present embodiment serve the beneficial purposes of reducing costs, simplifying manufacturing, reducing maintenance against wear and tear and providing for simple and efficient recycling of the thermoplastic used to construct such articles as may be thermoformed according to the triple sheet methodology.]

[0035] [In still yet another embodiment of the present invention, a reinforced heavy-duty racking pallet constructed out of three sheets of thermoplastic material is proposed. An object of the heavy-duty racking pallet is to provide a load supporting deck structure that encapsulates a rigid thermoplastic member that provides increased flexural strength and stiffness. Advantages of this arrangement include a pallet that is lightweight, lower in cost and is 100% recyclable, can be reprocessed [reprocesses] without knockdown or other added costs and superior racking strength.]

[0036] [Other features, objects and advantages of the present inventions will become apparent from the following description and appended claims when taken in conjunction with the accompanying drawings.]

DESCRIPTION OF THE DRAWINGS

[0037] [FIG. 1 is a perspective view of one embodiment of a triple sheet thermoforming machine;]

[0025.1] FIG. 1 is a perspective view of one embodiment of a triple sheet thermoforming machine;

[0038] [FIG. 2 is a schematic side elevation view showing the sequences of one of the triple sheet methods proposed in the present invention;[.]]

[0026.1] FIG. 2 is a block diagram showing the seven steps of the apparatus;

[0039] [FIG. 3 is a perspective view of a nesting pallet;]

[0027.1] FIG. 3 is a schematic side elevation view showing the seven steps of FIG. 2 at the form station of the apparatus;

[0040] [FIG. 4 is a sectional perspective view showing only the top and bottom members of the triple sheet article presented in FIG. 3;[.]]

[0028.1] FIG. 4 is a perspective view of an exemplary triple sheet article;

[0041] [FIG. 5 is a sectional perspective view showing the middle member of the triple sheet article shown in FIG.3;[.]]

[0029.1] FIG. 5 is a sectional perspective view showing the top formed sheet of the triple sheet article shown in FIG. 4;

[0042] [FIG. 6A is a partial side elevation view showing the nesting characteristics of the triple sheet article illustrated to advantage in FIG. 3;[.]]

[0030.1] FIG. 6 is a sectional perspective view showing the middle formed sheet of the triple sheet article shown in FIG. 4;

[0043] [FIG. 6B is a fragmentary cross sectional view showing the triple sheet article of FIG. 3;]

[0031.1] FIG. 7 is a sectional perspective view showing the bottom formed sheet of the triple sheet article shown in FIG. 4;

[0044] [FIG. 7 is a perspective view showing the top member of another representation of a triple sheet article processed in accordance with sequences, methods and apparatus presented in FIG.2;[.]]

[0032.1] FIG. 8 is cross section of one experimental triple sheet article;

[0045] [FIG. 8 is a perspective view of a middle member of the triple sheet article shown in FIG. 7;]

[0033.1] FIG. 9 is a cross section of a second experimental triple sheet article;

[0046] [FIG. 9 is a perspective view showing a [the] bottom member of the triple sheet article shown in FIG.7;[.]]

[0034.1] FIG.10 is a partial cross section of the second experimental triple sheet article of FIG. 9.

[0047] [FIG. 10 is a schematic side elevation view showing another method sequence of the present invention;[.]]

[0035.1] FIG. 11 is a perspective view showing yet another triple sheet article made by the apparatus;

[0048] [FIG. 11 is a side elevation view in partial section showing one embodiment of a triple sheet article according to FIG. 10;[.]]

[0036.1] FIG. 12 is a sectional perspective view showing the top formed sheet of the triple sheet article shown in FIG. 11;

[0049] [FIG. 12 is a perspective view of a [the] top member of the article of FIG. 11;[..]]

[0037.1] FIG. 13 is a sectional perspective view showing the middle formed sheet of the triple sheet article shown in FIG. 11;

[0050] [FIG. 13 is a perspective view of a [the] reinforcing member of the article of [referred to in] FIG. 11;[.]]

[0038.1] FIG. 14 is a sectional perspective view showing the bottom formed sheet of the triple sheet article shown in FIG. 11;

[0051] [FIG. 14 is a perspective view of a [the] middle member of the article of [referred to in] FIG. 11;[.]]

[0039.1] FIG. 15 is a perspective view showing the combination of the article shown in FIGS. 4 and 11;

[0052] [FIG. 15 is a perspective view of the bottom member of the article of [referred to in] FIGS. 9 and 10;[.]]

[0040.1] FIG. 16 contains Charts 1, which characterizes the operation of the apparatus;

[0053] [FIG. 16 is a schematic side elevation view showing another method sequence of the present invention;[.]]

[0041.1] FIG. 17 contains Charts 2, 3 and 4, which summarize the operation of the ovens relative the three sheets thermoformed by the apparatus;

[0054] [FIG. 17 is an enlarged partial view of [Drawing F of] FIG. 16F;[.]]

[0042.1] FIG. 18 contains Chart 5, which characterizes the controllable heater output of the invented apparatus relative the operation shown in FIG. 16;

[0055] [FIG. 18 is an enlarged partial view of another version [of Drawing F] of FIG.17F;[.]]

[0043.1] FIG. 19 contains Chart 6, which characterizes the constant heater output of the prior art;

[0056] [FIGS. 19A and B are plan views of the apparatus disclosed in FIG.18;[.]]

[0044.1] FIG. 20 is a perspective view identifying the prior art apparatus in phantom and the invented apparatus is full line detail;

[0045.1] FIGS. 21A and 21B are plan views of two embodiments of mold shuttle systems confined inside a platen;

[0057] [FIG. 20 is a perspective view showing the apparatus of the present invention;[.]]

[0046.1] FIGS. 22A and 22B are plan views showing the relative movement of another embodiment of the mold shuttle system of the preferred apparatus; and

[0058] [FIGS. 21A and B are plan views of two embodiments of a [the] slide apparatus inside a [the] platen;[.]]

[0047.1] FIG. 23 is a plan view suggesting yet another alternate means for operation of a mold shuttle system of the apparatus of triple sheet thermoforming.

[0059] [FIGS. 22A and B are plan views showing the relative movement of the slide apparatus; and[.]]

[0048.1] FIG. 24 is a plan view of an exemplary automated triple sheet thermoforming work cell.

[0060] [FIG. 3 is a [FIGS. 23A, B and C are] side elevation view [views] of article embodiments requiring control specific to the heat absorption characteristics of triple sheet articles.]

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0061] [The triple sheet thermoforming machine **2** shown in FIG.**1**, broadly considered, includes a first load/unload station **4**, a second pre-heat oven station **6**, a third final heat oven station **8**, and a fourth forming station **10**. Also included in thermoforming machine **2**, is wheel **12**, comprising a first clamp frame **14** [114], a second clamp frame [2] **16**, a third clamp frame [3] **18** and a fourth clamp frame [4] **20**. [The wheel] Wheel **12** rotates clockwise about a shaft **21** at axis **22** driven by a suitable motor (not shown) in a known manner.]

[0049.1] A triple sheet thermoforming machine **2**, as broadly considered in FIG. 1, includes a first load/unload station **4**, a second oven station **6**, a third oven station **8**, and a fourth forming station **10**. Although the arrangement of the preferred machine is

configured in a rotary style having four quadrants, five and six quadrant machine configurations fall within the scope of the invention. Further, although a rotary configuration is preferred, a linear machine configuration can also be developed falling within the scope of the present invention.

[0062] [First load/unload station **4** includes a load/unload table **24**, which operates in vertical motion to deliver thermoplastic sheet **25** to frames **14, 16, 18 and 20**. Above [said] table **24**, and [above said] wheel **12**, resides a first top oven **26**. Second pre-heat oven station **6** includes a second top oven **28** and a first bottom oven **30**. Third final heat oven station **8** includes a third top oven **32** and a second bottom oven **34**. The five ovens **26, 28, 30, 32 and 34** are shrouded in sheet metal **35** to reflect the radiant energy emitted from electric infrared heaters **36**. First top oven **26** operates to travel upward to prevent articles rotating into [the] load/unload station **4** from [the] form station **10** from impacting against [the] sheet metal **35** [36] shrouding oven **26**. First top oven **26** is controlled [37] to travel upward at the end of each complete part production cycle.]

[0050.1] Also included in the preferred four station rotary machine configuration is a wheel **12**, the wheel comprising a first clamp frame **14**, a second clamp frame **16**, a third clamp frame **18** and a fourth clamp frame **20**. The clamp frames support the thermoplastic sheets around their edges and carry the sheets through the machine. Wheel **12** rotates clockwise or counter-clockwise, depending upon the preference of the practitioner, about a central shaft **22**, and is driven by a suitable controllable motor (not shown) in a known manner. The perimeter margin of the wheel is supported upon rollers that are mounted upon the machine frame in known manner.

[0063] [Fourth forming station **10** includes a lower platen **38** and an upper platen **40**. Upon [said] lower platen **38** resides a second thermoforming mold [2] **42**. Upon [said] upper platen **40** resides a first thermoforming mold [1] **44** and a third thermoforming mold [3] **46** (see Figure 2) [(both not shown)]. Also upon upper platen **40** is slide structure **48**, which operates to shift thermoforming molds **44 and 46** laterally into positions aligned vertically with frames **14, 16, 18 and 20** as they traverse into [the[form station **10**. Lower and upper platens **38 and 40** further include lower and upper mechanical platen drive motors **[56]** (not shown) which operate to extend and retract the [said] platens in selected vertical and mold relative alignment with the frames carrying sheet about lower gear racks **58** and upper gear racks **60**. Included with lower platen **38**, and optionally with upper platen **40**, are auxiliary apparatuses [apparatus **62]** for extending the platens further to compress the surfaces of thermoforming molds **42, 44 and 46** against each other to complete the fusing procedures contemplated in the preferred embodiments of the present invention. Such auxiliary apparatus **[62]** may include, but are not limited to, bolster plates **59**, air

bags **61** receiving compressed air, [and] bayonets **63**, [and,] electromechanical platen drives [**61A**], linear transducers [**59**A] and platen brakes [**63A** (**61A**, **59A** **and** **63A** not shown)]. Both sets of apparatus are operable to interlock the platens relative to the other to facilitate the selective fusing of three sheets through the heat and compression of the present invention.]

[0051.1] First load/unload station **4** includes a load/unload table **24**, which operates in vertical motion to successively deliver thermoplastic sheet **25** to frames **14, 16, 18** and **20** and to receive articles from the form station for extraction from the machine. Although the apparatus may be charged with sheet manually, it is known in the industry that automated sheet delivery systems interfacing with the load/unload station can be deployed to serve a number of known purposes. Furthermore, it is also know that dissimilar sheet may be utilized in the construction of unitary articles, and therefore the automated sheet delivery system may be adapted to selectively charge the apparatus with a plurality of dissimilar sheet stored in adjacent piles, as will be more fully described below.

[0064] [Also seen in FIG. **1** are other apparatuses [apparatus] necessary for the triple sheet thermoforming machine **2** proposed in the preferred embodiments. Computer console [counsel] **64** is shown in close proximity to a PLC **66**. [which] PLC **66** controls switching gear (not shown) controlling ovens **26,28,30,32 and 34** in an oven control cabinet **68**. Also included, but not shown, are infrared sensors [**70**] that operate to adjust oven temperatures in response to variation. Also shown is an inventory of rigidizing structures **72**, which can be placed within the thermoplastic articles that may be thermoformed according to the triple sheet methodology. An automated [Automated] mechanical apparatus **74** acts to deliver [is also shown to demonstrate means delivering] structures **72** to desired positions within form station **10** in cooperation with the twin and triple sheet fusing procedures proposed in the production of thermoplastic articles according to the present invention. Additionally disclosed in reference to PLC **66** are controls (not shown) instructing clamp frames **14, 16, 18 and 20** to open or remain closed in phase with the triple sheet methodology deployed to make the triple walled articles of the present invention. Also shown in reference to PLC **66** are conventional machine controls and novel form station controls for the operation of the triple sheet thermoforming machine, which include platen functions and slide apparatus instructions.]

[0052.1] At the first load/unload station **4**, above the wheel, resides a first top heater bank **26**. At the second oven station **6** is a second top heater bank **28** and a first bottom heater bank **30**. At the third oven station **8** is a third top heater bank **32** and a second bottom heater bank **34**. The five heater banks **26, 28, 30, 32** and **34** are shrouded in sheet metal **35** to contain and reflect the radiant energy emitted from electric infrared

heaters **36** to the heat absorbing thermoplastic sheets. First top heater bank **26** operates to travel upward to prevent articles rotating into load/unload station **4** from form station **10** from impacting against sheet metal **35** shrouding oven **26.** First top heat bank **26** is optionally and selectively controlled to travel upward at the end of each complete part production cycle.

[0065] [[Before moving on to] FIG. **2**[, which] illustrates one possible triple sheet forming sequence of the present invention [to advantage, it will be seen that only partial side elevation views of the apparatus of thermoforming machine **2** are provided to simplify description of the proposed embodiment]. Also, it is understood that the terms "to mold", "molding" and "molded" are used to refer to the process by which a thermoplastic sheet is permanently displaced against the surface of a mold by the combined effects of heat, differential pressure and cooling.]

[0053.1] The fourth forming station **10** comprises a lower platen **38** and an upper platen **40**. The platens are opposed in vertical alignment and travel from open positions to closes positions, as will be described in more detail below. Upon lower platen **38** resides thermoforming mold **42.** Associated with upper platen **40** are thermoforming molds **44** and **46.** Interfacing with the upper platen **40** is a mold shuttle system **48.** The mold shuttle system operates to selectively shift thermoforming molds **44** and **46** laterally into position upon the platen **40,** in a position vertically aligned with opposed mold **42** and frames **14, 16, 18** and **20** as these traverse into the form station **10** from the third oven station.

[0066] [[As presented in the separate drawings of] FIG. 2A [**2**, Drawing **A]** serves to demonstrate the molding of sheet **25a** upon upper mold **44**; the unclamping of sheet **25a** from first frame **14;** and, the retraction of upper platen **40** from sheet line **76** with sheet **25a** under vacuum upon first mold **44**. FIG. 2B [Drawing **B]** serves to demonstrate the molding of sheet **25b** upon second mold **42** located on lower platen **38**; and, the retention of molded sheet **25b** upon lower mold **42** in frame **16** at the sheet line **76**. FIG. 2C [Drawing **C]** serves to demonstrate the downward extension of upper platen **40** with molded sheet **25a** upon upper first mold **44** onto and against molded sheet **25b** upon second mold **42**; the upward compression of lower platen **38** against upper platen **40**; and, the selective fusing of portions of heated molded sheet **25a** to selected portions of heated molded sheet **25b,** thus completing the twin sheet formation and fusion of sheets **25a and 25b**. FIG. 2D [Drawing **D]** serves to demonstrate the ejection of molded sheet **25a** from upper mold **44**; the upward retraction of upper platen **40**; [and] the horizontal sliding action of second upper mold **46** into the vertically aligned position occupied earlier by first upper mold **44**; [and,] the further actions of the release of twin sheet **25a and 25b** from second frame **16**; and, the retraction,

while molded sheet **25b** is under vacuum upon lower mold **42**, of lower platen **38** from sheet line **76**. FIG. 2E [Drawing **E**] serves to demonstrate the molding of sheet **25c** upon [the] second mold **46** located upon [the] upper platen **40**; and, the retention of sheet **25c** under vacuum upon second upper mold **46** in third frame **18**. FIG. 2F [Drawing **F**] serves to demonstrate upward extension of lower platen **38**, carrying twin sheet **25a and 25b** upon lower mold **42** to molded sheet **25c** upon second upper mold **46**; the upward compression of lower platen **38** against upper platen **40**; and, the selective fusing of portions of molded sheet **25a** to selected portions of molded sheet **25c**, thus completing the triple sheet formation and [anf] fusion of sheets **25a, 25b and 25c**. Finally, FIG. 2G [Final Drawing **G**] serves to demonstrate the ejection of sheet **25c** from upper mold **46** and sheet **25b** from lower mold **42**; the retraction of upper platen **40** and lower platen **38** from sheet line **76**; the horizontal sliding action of first upper mold **44** into the vertically aligned position occupied earlier by second upper mold **46**; and, the retention of sheet **25c** in third frame **18**, operable to carry the triple sheet article to load/unload station **4** to complete the triple sheet thermoforming operation.]

[0054.1] The lower and upper platens each include platen drive motors **50** that function to selectively open and close the platens to precise positions relative the operation of the apparatus. The press-like functions of the platens are stabilized and guided by a pair of column like gear posts **52** adjacent the four corners of each platen. Interfacing bearings **54** are provided there between for precise movement and control of the platens. Upper and lower platen disk brakes **56** and friction plates (not shown) are provided as means for locking the platens in select positions relative the thermoforming operations and for absorbing the stress of the loads associated with the thermoforming and compression functions of the apparatus.

[0055.1] Also associated with the press-like aspects of the platens are means to compress heat deformable sheets between the molds in order to thermally bond or cross-link the interfacing surfaces as will be described in more detail below. The conventional means for thermally fusing the upper sheet to the lower sheet are described in U.S. Patents 3,925,140 and 3,868,209, and are incorporated herein by such reference. Alternate means for achieving the press-like functions of the thermal fusing process joining a combination of heat deformable sheets are also disclosed in U.S. Patent 5,800,846, which is also hereby incorporated by such reference. The means of '846 are an improvement over the means of '140 and '209. '846 uses an array of position-controlled hydraulic pistons, in place of the air bags that are inflated with compressed air in '140 and

'209. Both means perform the incremental closing action compressing the sheets together in a forging-like manner. Both sets of apparatus in the present invented apparatus are operable to interlock the platens at relative positions with respect to the joining of the first combination of thermoplastic sheets and the second combination of thermoplastic sheet to facilitate the selective fusing of three sheets through the heat and compression of the present invention.

[0067] [The triple sheet article proposed in the triple sheet method shown in FIG. **2** is illustrated to advantage in FIG. **3, 4, 5, 6A and 6B.** Triple sheet article **200** represents one of the many proposed embodiments of the invention, and is a nesting pallet **202.** As can be seen, nesting pallet **202** comprises a first sheet **25c** forming a substantially flat load supporting deck **204** and nine depending legs **206**, and a second sheet **25b** forming a deck under carriage **208** and nine supporting legs **210**, that are vertically disposed beneath and receive depending legs **206.** Second sheet **25b** forming deck under carriage **208** also includes a plurality of raised bosses **212**, bridging bosses **214** and stiffening ribs **216**. [The relationship of first sheet **25c** to second sheet **25b** is illustrated to advantage in the perspective sectional cut away view provided in FIG. **4**.]]

[0056.1] Other apparatus necessary for the triple sheet thermoforming machine 2 proposed in the preferred embodiments include computer console **64** shown in close proximity to a first PLC **66**. The first PLC **66** receives, sends and returns process control input and output data used by the machine operator. A second PLC (not shown) controls switching gear controlling the radiant heat emitters of oven banks **26,28,30,32** and **34** in an oven control cabinet **68.** Additional PLCs are provided to control the motor driving the wheel and the operational functions of the load/unload, clamp frame, platen, shuttle system apparatus. (Also included, but not shown, are infrared sensors within the three ovens that operate to adjust oven temperatures in response to variation from normal conditions.) An inventory of rigidifying structures **72**, for example, which can be placed within the thermoplastic articles that may be thermoformed by the apparatus, are also contemplated, and would be positioned adjacent the form station as will be described below. In this connection automated mechanical apparatus **74** acts to deliver structures **72** and other desirable insert objects to desired positions within the form station **10** in cooperation with the twin and triple sheet fusing procedures proposed in the production of thermoplastic articles according to the present invention.

[0068] [Also included in nesting pallet **202**, is third sheet **25a**, which is shown for better effect in FIG. **5**. As can be seen, third sheet **25a** is engineered to stiffen nesting pallet **202** and to

maintain first and second sheets **25c and 25b** in spaced parallel relation. Third sheet **25a** forms rigid structure **218**, comprising a plurality of raised ribs **220** that extend upward to meet first sheet **25c**, and a plurality of recessed ribs **222** that extend downward to meet second sheet **25b**. Also included in third sheet **25a** are nine rigid leg structures **224** that bridge the gap **226** (see FIG. 4) formed between the legs **206** and **210** of sheets **25c** and **25b**, respectively, to reinforce the nine nesting pallet legs **228.** Also understood is that raised bosses **212** bridge the gaps **230** formed between the recessed ribs **222** molded into third sheet **25a**, such that the bosses **212** and ribs **222** combine to produce a strong pallet structure able to withstand the stresses expected to be experienced by the nesting pallet **202.**]

[0057.1] Turning now to the block diagram of FIG 2 and the corresponding schematic side elevation view taken at the form station in FIGS. 3A-G, one process sequence of the apparatus of machine **2** is described for illustrative purposes. FIGS. 2A and 3A serve to demonstrate the molding of sheet **25b** upon lower mold **42**; the unclamping of sheet **25b** from first frame **14;** and, the retraction of lower platen **38** from sheet line **76** with sheet **25b** under vacuum upon mold **42**. (Mold **44** would be used as a plug assist in the formation of sheet **25b** upon mold **42.**) FIGS. 2B and 3B serve to demonstrate the molding of sheet **25a** upon mold **44** located on upper platen **40**; and, the retention of molded sheet **25a** upon mold **44** in frame **16** at the sheet line **76**. FIGS. 2C and 3C serve to demonstrate the upward extension of lower platen **38** with molded sheet **25b** upon mold **42** into and against molded sheet **25a** upon mold **44**; the upward compression of lower platen **38** against upper platen **40** by movement of the bolster plate **59** caused by actuators **61**; and, the selective fusing of portions of heated sheet **25a** to selected portions of heated sheet **25b**, thus completing the twin sheet formation and cross linking fusion of sheets **25a** and **25b** comprising the twin sheet sub-assembly. FIGS. 2D and 3D serve to demonstrate the ejection of sheet **25a** from mold **44**; the upward retraction of upper platen **40**; the horizontal sliding action of second mold **46** into the vertically aligned position occupied earlier by mold **44**; the further actions of the release of twin sheet sub-assembly **25a** and **25b** from second frame **16**; and, the retraction, while molded sheet **25b** is under vacuum upon mold **42**, of lower platen **38** from sheet line **76**. FIGS. 2E and 3E serve to demonstrate the molding of sheet **25c** upon second mold **46** located upon upper platen **40**; and, the retention of sheet **25c** under vacuum upon mold **46** in third frame **18**. FIGS. 2F and 3F serve to demonstrate the upward extension of lower platen **38**, carrying twin sheet sub-assembly **25a** and **25b** upon lower mold **42** into contact with sheet

25c upon mold **46**; the upward compression of lower platen **38** against upper platen **40** by movement of the bolster plate **59** caused by actuators **61**; and, the selective fusing of portions of molded sheet **25a** to selected portions of molded sheet **25c**, thus completing the triple sheet formation and cross link fusion of sheets **25a, 25b** and **25c** into a unitary triple sheet article **200**. Finally, FIGS. 2G and 3G serves to demonstrate the ejection of sheet **25c** from upper mold **46** and sheet **25b** from lower mold **42**; the retraction of upper platen **40** and lower platen **38** from sheet line **76**; the horizontal sliding action of mold **44** into the vertically aligned position occupied earlier by mold **46**; and, the retention of sheet **25c** in third frame **18**, which is operable to carry the unitary triple sheet article to the load/unload station **4**, which completes the triple sheet thermoforming operation.

[0069] [First, second and third sheets **25a, 25b and 25c**, when heated to a thermoformable state, are permanently fused together to form a single triple sheet article **200** through the application of pressure produced by the sequential compression of molds **44** and **42**, and molds **46** and **42**, between platens **38** and **40** in the triple sheet thermoforming sequence illustrated [to advantage] in FIG. **2**. In particular, [it will be understood that] a plurality of selective fusion points will occur at the places where third sheet **25a** extends upward to meet first sheet **25c**, where third sheet **25a** extends downward to meet second sheet **25b**, and about the perimeter flange **232** of nesting pallet **202** where a margin **234** of sheet **25c**, a margin **236** of sheet **25b** and a margin **238** of sheet **25a** overlap to form [under compression] a compressed and a resilient seam **240** (see FIG. 6B).**]**

[0058.1] The triple sheet method sequence performed by the apparatus in FIGS. 2 and 3 is used to produce, for example, the unitary triple sheet articles shown in FIGS. 4 through 13. It is to be understood that the apparatus can manufacture a wide range of other end products for a variety of end market applications.

[0059.1] In the series of FIGS. **4, 5, 6** and **7** triple sheet article **200** is represented. Article **200** of FIG. 4 is a nine-leg pallet **202** and is comprised of sheets **25a, 25b** and **25c**, one quarter (1/4) sections of which are shown in FIGS. **5, 6** and **7.** The triple sheet pallet **202** involves a substantially flat load supporting surface **204** formed by sheet **25c** a triple walled load bearing surface **206**, formed from sheets **25a, 25b** and **25c**, and double walled legs **208** for static load bearing strength. As may be appreciated by those skilled in the plastic pallet arts, the construction of pallet **202** shown in FIG. 4 would be considerably stronger than the prior art twin sheet construction suggested in U.S. Patent 4,428,306. Further more, the triple sheet apparatus allows a pallet with both a flat deck

and double walled legs to be instantly manufactured, which overcomes a number of problems associated with twin sheet pallets.

[0070] [In FIG. **6**A two nesting pallets **202** are shown to illustrate the nesting characteristic of the proposed triple sheet article **200.** As shown, depending leg **206** of first sheet **25c** receives supporting leg **210** of sheet **25b**, shown in phantom, to enable nesting and consolidated storage and shipment of triple sheet articles **200**.]

[0060.1] The dramatic increase in triple sheet pallet strength as measured against twin sheet pallet strength has been demonstrated and confirmed through experimentation, as will be described below. Three state of the art nine legged twin sheet pallets, each having a unique rigidifying methodology, which will be known by referring to U.S. Patents 5,566,624, 5,401,347 and 5,996,508, were reproduced using aluminum tooling in ¼ scale (24 x 20-inch). High-density polyethylene (BA50100 or the equivalent HDPE) sheet with a starting gauge of .105 inches in cross section was procured and work pieces of each of the three representative twin sheet articles were produced. The three groups of work pieces each had a final over-all wall thickness of .210 inches and finished part weights of 3.5 lbs. Next the three aluminum twin sheet tool sets were reconfigured to simulate the three rigidifying methods in corresponding triple sheet construction. HDPE sheet with a starting gauge of .070 inches was procured and triple sheet samples from each reconfigured mold group were produced. The technique used to simulate a triple sheet machine was crude, but nonetheless effective. Two thermoforming machines were used. The rigidifying center sheet was thermoformed upon a first (single station) machine, and the resulting part was manually transported and placed between top and bottom sheets formed on a twin sheet machine in conventional manner before these top and bottom sheets were compressed together in a typical twin sheet phase. The resulting triple sheet work pieces each had a final over-all wall thickness of .210 inches and finished part weights of 3.5 lbs.

[0071] [[Triple sheet article **200**, as shown in FIGS. **3, 4, 5 and 6**, is offered to demonstrate the unique and novel features, objects and advantages that the triple sheet thermoforming methods and apparatus invented and proposed herein have to advance the art in the end market application to which the invention is applied. In the case of triple sheet article **200**, it will be seen that the] The triple sheet nesting pallet **202** advantageously has a substantially flat load supporting deck surface **206.** This arrangement provides increased areas of surface contact and load support, thereby [and is an feature] overcoming problems of twin sheet nesting pallets

characterized in U.S. [US] Patent No. 4,428,306 [to Penda] which proposes a network of deck recesses for the purposes of reinforcement and stiffening. The proposed arrangement of a substantially flat deck **206**, reinforced and supported by rigid structure **218**, also uniquely overcomes the fluid and debris buildup problems associated with twin sheet pallet decks extensively recessed to form knit or fusion points with underlying molded sheets, as is characterized by U.S. [US] Patent No. 5,391,251 [to Shuert]. Finally, [the] rigid structure **218** thermoformed from sheet **25a** and encapsulated between sheets **25c and 25b** is an advantageous and novel approach to the manufacture of nesting pallets. This arrangement offers an alternative approach to reinforcing nesting pallets thermoformed according to the twin sheet methodology with metal, wood or non-thermoplastic reinforcing bars and members, such as is set forth is U.S. Patent Nos. [US Patents] 5,596,933 [to Fabri-Form] and 5,042,396 [to Shuert]. The arrangement illustrated to advantage in FIG. **2** produces a superior thermoplastic triple sheet article **200** that is lightweight, resistant to permanent deflection cause by the bending or failure of the non-plastic reinforcing member, that is easy, safer and lower cost to manufacture, and is 100% recyclable for efficient and economical reprocessing. Accordingly, it is seen that the triple sheet methods and apparatus disclosed herein provide a significant leap forward in the art to which the invention is applied.]

[0061.1] All six groups of work pieces were simply supported along the two 24 inch edges and a 4-inch diameter load with progressively increasing weights was applied upon the center of the work pieces. The resulting deflection simulating a racking load was measured on each group of work pieces at each incremental load. The averages of the raw data points of these test results are summarized below in Table 1.

Table 1

AVERAGE TEST DATA RESULTS – Deflection measured in inches

	O LB.	5 LB.	10 LB.	15 LB.	20 LB.	25 LB.	30 LB.
5,401,347 Twin Sheet	0	0.0125	0.305	0.425	0.5875	0.9875	
5,996,508 Twin Sheet	0	0	0.0325	0.42	0.795	1.12	
5,566,625 Twin Sheet	0	0	0.0275	0.22	0.5075	0.825	
5,401,347 Triple Sheet	0	0	0.035	0.07	0.4825	0.7025	0.935
5,996,508Triple Sheet	0	0.0125	0.035	0.17	0.415	0.63	0.875
5,566,625 Triple Sheet	0	0	0.03	0.375	0.79	1.22	

[0072] [Referring again to FIG. **2,** it will be understood that the procedures of the triple sheet methodology [exemplified in Drawing **A** through **G]** can be applied to the manufacture of triple sheet article **300**, shown to advantage in FIGS. **7, 8 and 9.** Triple sheet article **300** is known within the material handling industry as a load distributor **302.** Load distributor **302** operates to distribute over a wider area the focused pressure transferred by the legs **228,** such as is disclosed in nesting pallet **202,** upon the contents of a loaded pallet to reduce possible damage. Efforts have been made to further increase the load bearing strength of twin sheet molded load distributors, and U.S. [US] Patent No. 5,758,855 to Cadillac teaches the placement of a flexible tensile member within the pallet structure to increase flexural strength of the load distributor. Although the Cadillac arrangement is an advancement upon prior load distributing articles, it has several problems that are overcome with the novel methodology of triple sheet thermoforming.**]**

[0062.1] Thus, a review of the data in Table 1 indicates the summary results shown in Table 2:

Table 2

Average Deflection Results at a 25 lb. Load in Inches

	Twin	Triple	Results
5,401,347	.9875"	.7025"	+ 29%
5,996,508	1.12"	.63"	+ 44%
5,566,625	.825"	1.22"	- 48%
Average Deflection	.986"	.85"	+ 14%
Strongest Twin Sheet Vs Strongest Triple Sheet at 25 lbs.	.825"	.63"	+ 24%

[0073] [As seen in FIG. **7**, load distributor **302** includes [is illustrated to advantage. Load distributor **302** comprises] an upper deck **304** formed from sheet **25a**, a rigidizing structure **306** formed from sheet **25c** and load distributing surface **308** formed from sheet **25b**. Upper deck **302** includes raised deck portions **310** elevated above the rectangular plane **312** formed by [the] outer margins 314 [316] and inner margins **316** of sheet **25a**. Interposed between [the] raised deck portions **310** and [the outer and inner] margins **314** and **316** are substantially perpendicular surfaces **318,** [and] outer ramp surfaces **320** and inner ramp surfaces **322.** Inner margins **314** and inner ramp surfaces **322** define four load distributing surface cutouts **324.** Outer and inner ramp surfaces **320** and **322,** respectively, are adapted to allow the wheels of a pallet jack to cross over the raised deck portions **310** to access cutouts **324** from the four sides of load distributor **302.** Also provided in load distributor **302**, may be a plurality of leg receiving elements **326a** or **326b** (shown in phantom) suitable for locating and retaining the legs **228** in position upon upper deck **304.]**

[0063.1] The experimentation conclusively demonstrated that triple sheet apparatus yields a significantly stronger structure than twin sheet apparatus. With respect to the loss of strength in the 5,566,625 triple sheet work pieces, one will appreciate by a review of the patent figures of '625 that the distribution of material in this arrangement is heavily concentrated along the lower plane of elevation. This is in stark contrast to the

5,996,508 arrangement wherein the material of the middle sheet is substantially evenly distributed between the upper and lower planes. These two relationships may be more fully appreciated by referring to FIG. 8, which characterizes '508 and FIG. 9, which characterizes '625. Accordingly, it may be appreciated that more strength is generated when the triple sheet construction is more evenly distributed in the fashion of a honeycomb construction or a box frame design.

[0074] [[As seen in more detail in] FIG. **8** shows [is] rigidizing structure **306** thermoformed from sheet **25c** in the proposed triple sheet methodology. [It is understood that structure] Structures **306** is engineered to stiffen load distributor **302** and maintain upper deck **304** and load distributing surface **308** in space parallel relation. Structure **306** comprises raised ramp support bosses **330**, perpendicular surface bosses **332,** raised leg supporting bosses **334** and ribs **336** bridging the gaps **338** formed between the ramp support bosses **330** and the leg supporting bosses **334**. Also included in structure **306,** are outside margins **340** defining the perimeter border **342** and inside margins **344** defining four cutouts **346** adapted to accommodate the wheels of a pallet jack from the four sides of the load distributor **302.]**

[0064.1] A second consideration was that the 5,566,625 triple sheet work pieces were much more difficult to simulate in triple sheet than either of the 5,401,347 or 5,996,508 approaches. In the simulation of '625 the surfaces of the lower plane **210** of the center sheet **212** fell below the hot tack adhesion temperature required for cross linking of the plastic material and the construction that resulted is more like that which is shown in FIG. 10. The end results were detrimental rather than beneficial. The experiment strongly suggests that the distribution of plastic is a critical factor contributing to strength.

[0075] [Load distributing surface **308**, formed from sheet **25b** in the proposed triple sheet method, is illustrated [to advantage] in FIG. **9**. Load distributor surface **308** is shown to be flat and operates to distribute over a wider area the focused pressure transferred by the legs **228** of loaded pallet **202**. Also included in load distributor surface **308** are four cutouts **348**, inner cutout margins **350** and outer margins **352**. As will be understood, when structure **306** and surface **308** are compressed together in the triple sheet procedure represented by [Drawing **C]** of FIG. 2C [2], structure **306** and underlying surface **308** will be selectively and permanently fused together by the combined effects of thermal bonding and pressure in the overlapping margins **340** and **344** of structure **306** and underlying margins **350** and **352** of surface **308.** Partial representations of the areas of select fusing **354** are shown to advantage in phantom in FIG **9** such that[. As can be seen] a permanent bond is created therebetween to form a resilient seam **356**. Although not disclosed in FIG. **9**, it is possible to increase the flexural stiffness of load distributor **302** by forming upward

extending underlying bosses [**358** (not shown)] in surface **308**, such that these bosses [**358**] extend upward to bridge the vertical surfaces **360** of bosses **330**, **332** and **334** and ribs **336** formed in structure **306** of load distributor **302**.]

[0065.1] In interpreting the results another factor must be considered. Not only was the simulation of the triple sheet apparatus crude, in that two machines were used in tandem, it should also be noted that the full design flexibility and complexity of triple sheet was not implemented in the work pieces. In particular, neither of the top or bottom sheets included any reinforcing structures because of the simulation's limitations. For example, load bearing strength would be dramatically increased by providing the structures of 5,996,508 in the middle sheet and the structures of 5,566,625 at a right angle to the '508 structures on the lower sheet, so that the structure of '625 could reinforce and deflect loads upon the '508 structure. Therefore, although the test results showed a dramatic improvement in average strength in the order of 24 percent, with full implementation of the methodology and processing benefits of the invented apparatus, the improvement in load bearing strength would be considerably higher and therefore a important break through to overcome the significant shortcomings identified above.

[0076] [Triple sheet article **300**, as shown in FIGS. **7, 8 and 9**, is offered to demonstrate the unique and novel features, objects and advantages that the triple sheet thermoforming methods and apparatus invented and proposed herein have to advance the art in the end market application to which the invention is applied. It is seen that twin sheet articles, such as load distributors, can be reinforced to significant advantage with thermoplastic members molded in the triple sheet methodology rather than by non-thermoplastic members such as is disclosed in the prior art. The triple sheet article shown here for example produces a lower cost, lighter weight and 100% thermoplastic article that provides the flexural stiffness that is required for the application. Additionally, it will be seen that in the present example, [the] ramp support bosses **330** and bridging ribs **336** provide significant compressive strength in the raised deck portions **310** where the wheels of a pallet jack are introduced to transport the loaded pallet from location to location. Accordingly, it is seen that the triple sheet methods and apparatus disclosed herein provide a significant leap forward in the art to which the invention is applied.]

[0066.1] Referring now to the series of FIGS. 11 through 14, it will be understood that the method sequence of FIGS. 2 and 3 of the triple sheet apparatus can also be applied to the manufacture of triple sheet article **300**, which is known within the material handling industry as a load distributor **302**. Load distributor **302** operates to distribute over a wider area the focused pressure transferred by the legs **208**, such as is

disclosed in reference to pallet deck **202**, upon product stored in static condition. As seen in one quarter (1/4) section views of FIGS 12, 13 and 14, load distributor **302** includes an upper deck **304** formed from sheet **25b**, a rigidizing structure **306** formed from sheet **25a** and load distributing base **308** formed from sheet **25c**.

[0077] [Referring again to FIG. 2, the separate Drawings **A through G** are presented to describe the need for first upper oven **26** is needed above load/unload station **4**. In conventional twin sheet thermoforming methods and apparatus, oven stations **[6 and 8]** are required to preheat and heat two successive thermoplastic sheets to an elevated temperature suitable for thermoforming. But with [With] the addition of third thermoplastic sheet **25c** it is necessary to add extra heat capacity to facilitate the triple sheet process contemplated in the present invention. As is generally understood in the art of thermoforming HDPE, a rule of thumb is that 1 second or less of radiant heat for each 1/100 inch of material thickness is required to elevate the thermoplastic sheet to a suitable thermoforming state. Therefore, if the starting gauge of the thermoplastic sheet is .125 inches thick, a heating duration of 125 seconds or less within an oven having 30 wsi at 50% +/- average power output is required. According to the twin sheet methodology, 125 seconds of heat is applied to each sheet over a total duration split between the oven stations **[6 and 8]**. In this manner, the approximate duration of time the two successive sheets reside within each oven is +/- 62.5 seconds. It is also understood in the twin sheeting art that the formation of a first thermoplastic sheet over a first thermoforming mold is closely followed by the formation of a second thermoplastic sheet over a second thermoforming mold, which in turn is closely followed by the subsequent fusing of the two formed sheets while the first and second formed sheets remain at relatively high temperatures for the thermal bonding and selective fusing processes of the twin sheet methodology. Accordingly, it may be seen that in the twin sheet process there are heating periods, forming periods, fusing periods and cooling periods, which progress in known manner, such that the forming, fusing and cooling periods are substantially equal in length to the heating periods of the subsequent pair of thermoplastic sheets being heated in the oven stations [**6** and **8**].]

[0067.1] As seen in FIG. 15, pallet **202** and load distributor **302** are combined in a snap together manner to provide a rackable pallet **400** comprising a total of six thermoplastic sheets. The Triple sheet articles offered by way of example, which are not intended as a limitation on the scope of the invention, should serve to demonstrate the unique and novel features, objects and advantages that the triple sheet thermoforming apparatus invented and described herein have to advance the art in the end market application to which the invention apparatus is applied.

[0078] [In the triple sheet thermoforming process, the heating, forming, fusing and cooling periods may progress in unequal time duration. Thus, the total time permitted for each sheet in each of the three ovens may range in the order of +/- 66%. Specialized oven process control is therefore preferred to accommodate the varying heat cycles and time durations that sheets 1, 2 and 3 dwell in ovens 1, 2 and 3 in the triple sheet thermoforming apparatus. Accordingly, oven process control is used to equalize the total amount of heat that is applied to the 3 sheets as each sheet is indexed forward from oven 1 through oven 3. Table 1, shown below, serves to illustrate the amount of time each sheet dwells in the ovens of the proposed methodology:]

TABLE 1

	Oven 1	Oven 2	Oven 3	Total Time
Sheet 1	20	40	60	120
Sheet 2	40	60	20	120
Sheet 3	60	20	40	120
	120	120	120	

[0068.1] Referring now to the apparatus in detail, the separate FIGS. 2 and 3 suggest the need for a third oven, such as first oven bank **26** above the load/unload station **4**, to heat three successive sheets. In conventional twin sheet thermoforming apparatus, two oven stations are required to heat two successive thermoplastic sheets to an elevated temperature suitable for thermoforming. With the addition of a third thermoplastic sheet it is therefore necessary to add extra heat capacity to facilitate the triple sheet heating process contemplated in the present apparatus.

[0079] [In the current art it is standard to regulate the amount of energy emitted by the heaters of the oven according to percentage timers or the like. Also, an oven may be separated into two or more zones so that each zone can be independently regulated relative to several known factors. For example, zones within the oven corresponding to the outer margins of the sheet may be regulated to emit energy in the form of heat for six of every ten seconds while the zones corresponding to the center areas of the sheet may be regulated to emit energy in the form of heat for four of every ten seconds. Thus in the current art ovens are regulated independently and in constant ten +/- second intervals in phase with the single or twin sheet thermoforming methodology.]

[0069.1] As is generally known in the art of thermoforming high density polyethylene (HDPE), the rule of thumb understanding is that +/- 0.75 seconds of radiant heat for each 1/100 inch of material thickness is required to elevate the thermoplastic

sheet to a suitable thermoforming state. Therefore, if the starting gauge of the thermoplastic sheet is 0.125 inches thick in cross section, a heating duration of +/-94 seconds within an oven having 30 watts per square inch (wsi) at +/- 50% average power output would be required. According to the twin sheet methodology, the +/- 94 seconds of heat required to heat a sheet of HDPE would be applied to each sheet over a total duration split between the two oven stations. In this manner, the approximate duration of time the two successive sheets would reside within each oven is +/- 47 seconds, although the duration of time the first sheet spends in the first oven is usually less than the time spent in the second over, from a forming function stand point. It is also understood in the twin sheeting art that the formation of a first thermoplastic sheet over a first thermoforming mold is closely followed by the formation of a second thermoplastic sheet over a second thermoforming mold, which in turn is closely followed by the subsequent fusing of the two formed sheets while the first and second formed sheets remain at relatively high temperatures for the thermal bonding and selective fusing of the twin sheet methodology. Accordingly, it may be now understood that in the twin sheet process the heating period is timed to equal the combination of forming periods, fusing periods and cooling periods, which progress in known manner, such that the forming, fusing and cooling periods are substantially equal in length to the heating periods of the subsequent pair of thermoplastic sheets being heated in the two oven stations for the next twin sheet forming cycle. Although a +/- 47 second heat duration in each oven is suggested, the duration of time each sheet spends in each oven may be longer or shorter, but nevertheless, +/- 94 seconds overall. Further, compensation for sheets of different thickness in cross section is provided by constant heater output control at the two ovens of the twin sheet apparatus.

[0080] [In the triple sheet method, however, the amount of radiant energy applied to each sheet will vary according to the duration of time each sheet spends in each oven. It is also understood that Oven 1, with only a single upper bank of infrared heating elements, will have to be adjusted to increase its heat output for sheet 3 relative to sheet 1 of the proposed process because oven 1 normally produces 15+ wsi versus 30+ wsi for ovens 2 and 3, with two oven banks each. Therefore, rapid response infrared emitters are preferred in first upper oven **26**. A processing algorithm can be used to adjust the heater output of this and preferably all 5 ovens in order to match heater output to the heat absorption characteristics of the three sheets to be thermoformed according to the triple sheet method.]

[0070.1] In the current thermoforming art it is standard to regulate the amount of energy emitted by the heaters of the ovens of the twin sheet apparatus according to percentage timers or the like with the use of power switching devices such as solid state relays or silicon controlled rectifiers. Also, an oven may be separated into two or more zones so that each zone can be independently regulated relative several known factors. By way of example, heater output zones within the oven corresponding to the outer margins of the sheet may be regulated to emit energy in the form of radiant heat energy for six of every ten seconds (i.e. 60% output), while the zones corresponding to the center areas of the sheet may be regulated to emit energy in the form of radiant heat energy four of every ten seconds. Thus in the current art oven zones are regulated independently and in substantially constant ten or eight +/- second intervals in phase with the single or twin sheet thermoforming methodology. Oven output is therefor substantially constant in the twin sheet operation, and after warm-up calibrations is only adjusted in response to external variations.

[0081] [Therefore, heater output in the triple sheet methodology is further regulated by controllers relative to the duration of time that each of the three successive frames carrying three successive sheets dwells in the three ovens. Means of oven control and processing algorithms are objects for the triple sheet methodology.]

[0071.1] In the triple sheet apparatus, however, the amount of radiant energy applied to each sheet will vary according to the duration of time each sheet spends in each oven. It is also understood that the first oven **26**, with only a single upper bank of infrared heating emitters **36**, would have to be controlled to increase its heat energy output for sheet 3 relative to sheet 1 of the ongoing triple sheet operation for two reasons. First, sheet 3 resides in oven 1 for 31 percent of it total heat duration. Second, oven 1 normally produces 15+ wsi versus 30+ wsi for ovens 2 and 3, with two oven banks each. Therefore, rapid response infrared emitters are preferred in first upper oven **26**. A processing algorithm is used to adjust the heater output of this first oven bank, and preferably all five oven banks, in order to match heater output to the heat absorption characteristics of the three sheets to be thermoformed by the apparatus. Therefore, heater output in the triple sheet apparatus is further regulated by controllers relative to the duration of time that each of the three successive sheets dwells in the three ovens. Means of oven control and processing algorithms are required objects for the triple sheet apparatus.

[0082] [[Referring now to] FIG. **10[**, which] illustrates another possible triple sheet forming sequence of the present invention [to advantage, it will be understood that only partial side elevation views of the apparatus of thermoforming machine **2** are provided to simplify description of the proposed embodiment]. [As presented in the separate drawings of] FIG. 10A [**10**, Drawing **A]** serves to represent form station **10** and to demonstrate the molding of sheet **25a** upon upper mold **44a**,[;] the unclamping of sheet **25a** from first frame **14**,**[;]** and[,] the retraction of upper platen **40** from sheet line **76** with sheet **25a** under vacuum upon first mold **44a**. FIG. **10B** **[**Drawing **B]** serves to demonstrate the molding of sheet **25b** upon second mold **42a** located on lower platen **38[**;] and[,] the retention of molded sheet **25b** upon lower mold **42a** in frame **16** at [the] sheet line **76**. FIG. **10C** [Drawing **C]** serves to demonstrate the insertion of thermoplastic rigid member **27** onto molded sheet **25b** from above the sheet line. FIG. **10D** [Drawing **D]** serves to demonstrate the downward extension of upper platen **40** with molded sheet **25a** upon upper first mold **44a** onto and against molded sheet **25b** and rigid member **27**, both upon second mold **42a**[;]. FIG. **10E** also shows the upward compression of lower platen **38** against upper platen **40**[;] and[,] the selective fusing of portions of heated molded sheet **25a** to selected portions of heated molded sheet **25b,** as well as the bonding of heated thermoplastic sheets **25a and 25b** to rigid, optionally pre-treated, thermoplastic member **27[**, thus completing]. This completes the twin sheet formation of sheets **25a and 25b** and encapsulation of rigid member **27** therebetween. FIG. **10E** **[**Drawing **E]** serves to demonstrate the ejection of molded sheet **25a** from upper mold **44a**,[;] the upward retraction of upper platen **40**,**[**; and] the horizontal sliding action of second upper mold **46a** into the vertically aligned position occupied earlier by first upper mold **44a[**; and], the further actions of the release of twin sheet **25a and 25b** from second frame **16**,[;] and[,] the retraction, while molded sheet **25b** remains under vacuum upon lower mold **42a**, of lower platen **38** from sheet line **76**. FIG. **10F** [Drawing **F]** serves to demonstrate the molding of sheet **25c** upon the second mold **46a** located upon the upper platen **40[**;] and[,] the retention of sheet **25c** under vacuum upon second upper mold **46a** in third frame **18** at [the] sheet line **76**. Furthermore, FIG. **10G** [Drawing **G]** serves to demonstrate the upward extension of lower platen **38,** carrying twin sheets **25a and 25b** as well as encapsulated rigid member **27** upon lower mold **42a** to molded sheet **25c** upon second upper mold **46a**,[;] the upward compression of lower platen **38** against upper platen **40**,[;] and[,] the selective fusing of portions of molded sheet **25a** to selected portions of molded sheet **25c**, thus completing the triple sheet formation of sheets **25a, 25b and 25c**. Finally, FIG. **10H** demonstrates [Final Drawing **H** serves to demonstrate] the ejection of sheet **25c** from upper mold **46a** and sheet **25b** from lower mold **42a**,[;] the retraction of upper platen **40**[,] and lower platen **38** from sheet line **76**,[;] the horizontal sliding action of first upper mold **44a** into the vertically aligned position occupied earlier by second upper mold **46a**,[;] and, the retention of sheet **25c** in third frame **18**, operable to

carry the triple sheet article to load/unload station **4** to complete the triple sheet thermoforming operation.]

[0071.1] In the triple sheet apparatus, however, the amount of radiant energy applied to each sheet will vary according to the duration of time each sheet spends in each oven. It is also understood that the first oven **26**, with only a single upper bank of infrared heating emitters **36**, would have to be controlled to increase its heat energy output for sheet 3 relative to sheet 1 of the ongoing triple sheet operation for two reasons. First, sheet 3 resides in oven 1 for 31 percent of it total heat duration. Second, oven 1 normally produces 15+ wsi versus 30+ wsi for ovens 2 and 3, with two oven banks each. Therefore, rapid response infrared emitters are preferred in first upper oven **26**. A processing algorithm is used to adjust the heater output of this first oven bank, and preferably all five oven banks, in order to match heater output to the heat absorption characteristics of the three sheets to be thermoformed by the apparatus. Therefore, heater output in the triple sheet apparatus is further regulated by controllers relative to the duration of time that each of the three successive sheets dwells in the three ovens. Means of oven control and processing algorithms are required objects for the triple sheet apparatus.

[0083] [The resultant triple sheet article [proposed in reference to FIG. **10**] made in accordance with the process of FIGS. **10A-H**, is illustrated to advantage in FIGS. **11, 12, 13, 14 and 15.** Triple sheet article **400**, representing [represents] one of the many proposed embodiments of the invention, is a rackable pallet **402**. As can be seen in FIGS. 10 and 11 [FIG. **11**], racking pallet **402** comprises a first sheet **25b** thermoformed over mold **44a** to form a rectangular substantially flat load supporting deck **404,** a second sheet **25a** thermoformed over mold **42a** to form a deck under carriage **406** with nine supporting legs **408**, and a third sheet **25c** thermoformed over mold **46a** to form a lower support structure **410**. Optionally interposed between said first and second sheets **25b** and **25a** is thermoplastic rigid member **27,** also including nine [9] depending rigid legs **412,** which together combine to provide racking pallet **402** with added flexural stiffness.]

[0072.1] FIG. **16** comprises Chart 1 simulating the operational steps of the apparatus, starting from the first sheet charged into the machine to the tenth sheet charged into the machine. By the time Cycle 4 **80** is reached the machine is fully charged and the respective cycle times of the apparatus are set in substantially constant motion. By way of further explanation, the four stations and their operating functions are identified in the column headings. The introduction and movement of the successive sheets through

the four stations are identified in the row headings. Within the column and row cells are the time factors in seconds for each such operating function. Therefore, in CYCLE 1, sheet 1 is loaded into frame **14**, which takes up to 11 seconds, and sheet 1 is heated for 9 seconds in oven 1. In CYCLE 2 the wheel indexes forward by a ¼ turn in 5 seconds to move sheet 1 to oven 2, where it dwells for a period of 20.5 seconds. Meanwhile, sheet 2 is loaded into frame **16**, where after sheet 2 dwells in oven 1 for 10.5 seconds. In CYCLE 3, sheet 1 is indexed forward into oven 3 for a dwell period of 29.5 seconds, sheet 2 is indexed forward from oven 1 to oven 2 for a dwell period of 29.5 seconds, and sheet 3 is loaded into frame **18**, where after sheet 3 dwells in oven 1 for 18.5 seconds. In CYCLE 4 the wheel indexes forward and heated sheet 1 enters the form station where the lower platen extends upward in 3.5 seconds to vacuum form sheet 1 in 1.5 seconds, where after the platen dwells in this position for 10 seconds before frame **14** releases sheet 1 in 1.5 seconds and the lower platen retracts to an open position in 3.5 seconds. Concurrently, sheet 2 has moved to oven 3 for 20 seconds, sheet 3 moves to oven 2 for 20 seconds, and sheet 4 is loaded into frame **20** where after sheet 4 dwells in oven 1 for 9 seconds. In CYCLE 5, sheet 2 is indexed into the form station where the upper platen extends downward in 3.5 seconds to vacuum form the second sheet in 2 seconds, where after the lower platen extends up to close the sheet 1 against sheet 2 in 2 seconds, and the pressure form compression function occurs for 5 seconds, followed by a 10 second dwell period. Finally, frame **16** opens in 1.5 seconds, and the platens retract, with the twin sheet sub-assembly being carried away from the sheet liner by the lower platen. Concurrently, sheets 3 and 4 are indexed forward into the next ovens and frame **14** is charged with sheet 5, which dwells in oven 1 for 16.5 seconds. During the final stages of CYCLE 5 the upper platen retracts into position where a first mold is replaced by a second mold by means of the mold shuttle system during a 16.5 second period that overlaps CYCLES 5 and 6. In CYCLE 6 sheet 3 enters the form station and the upper platens extends downward in 3.5 seconds to vacuum form sheet 3 is 2 seconds, where after the lower platen extends up in 2 seconds to close the twin sheet sub-assembly against sheet 3, where after the pressure form compression phase is repeated for 5 seconds followed by 10 seconds of closed dwell time. The platens then retract while frame **18** remains closed. Concurrently, sheets 4 and 5 are indexed to the next ovens and sheet 6 is loaded into frame **16**. In CYCLE 7, the triple sheet article is indexed forward from the form station and is unloaded from the machine in

6 seconds. Sheet 7 is loaded into frame **18**, remaining in the oven 1 for 3 seconds and sheets 6 and 5 are indexed forward into the next ovens, and the fourth sheet enters the form station where the sequence of CYCLE 4 is duplicated in CYCLE 7, and operating functions continue thereafter in phase in the manner suggested.

[0084] [Now referring in greater detail to the FIGS. **12, 13, 14 and 15**, it will be seen that [the] load support deck **404** comprises a substantially flat deck surface **414** surrounded by a depending horizontal margin **416.** Joining [said] deck surface **414** and margin **416** are eight [8] perpendicular corner walls **418** and four [4] perpendicular inner walls **422.** Disposed between [said] corner walls **418** and extending outward from said inner walls **422** are a plurality of ribs **420** operable to absorb impacts and stiffen pallet **402.** Centrally located on the flat deck surface **414** are four depending recesses **424,** which extend down to the horizontal plane formed by margin **416** to form central select fusing surfaces **426**.]

[0073.1] Therefore, with respect to oven heater output and the time each sheet dwells within each oven, it will be seen in summary Charts 2, 3 and 4 of FIG. 17 that once CYCLE 7 is reached, the apparatus process sequence becomes stabilized and is repeated in continuous phase. Chart 2 summarizes the length of time each sheet spends in each oven. Chart 3 summarizes the amount of heat each sheet receives from each oven. Chart 3 shows the calculation of the level of heater output required at each oven to heat the three sheets to uniform temperatures for proper thermoforming. Therefore, for illustrative purposes, the heater output profile of the ovens from cycle to cycle could be characterized in Chart 5 of FIG. 18. This is quite different from the heater output profile of the prior art twin sheet apparatus as suggested in Chart 6 in FIG. 19.

[0085] [[Below load support deck **404** is rigid] Rigid thermoplastic member **27** is disosed below rigid termoplastic member **27**. Rigid thermoplastic member **27** is constructed out of the same thermoplastic material used to construct sheets **25a, 25b** and **25c.** Rigid member **27** is formed from a single sheet of heated thermoplastic expanded between two heated die plates to thermoform a hybrid honeycomb structure. As can be seen, rigid member **27** comprises a main deck support body **428** and optionally nine leg support structures **430.** [Centrally] Four cutouts **432** are centrally located in rigid member **27** [are four cutouts **432,** which, and cutouts **432** receive four depending recesses **424** formed in support deck **404.** Rigid member **27** is defined by outside boarder **434.**]]

[0074.1] It will now be appreciated that heater output control is essential for the operation of the invented apparatus. It is equally important that the infrared emitters are equal to the task as will be described below. Heat can be transferred to sheet in three

ways, namely conduction, convection or radiation. Infrared heat is one form of radiation that happens to best match the absorption characteristics of most thermoplastics, including the preferred HDPE. There are many options for radiating infrared heat. Some of the most common of these are electric heaters comprising calrods™, ceramic elements, panel heaters and quartz tubes. Quartz tubes are the industry standard when fast response is required. Quartz tube heaters can be quickly adjusted to match the requirements of different sheet thickness and oven duration times (i.e. the time a sheet dwells in an oven). Electric heaters used in the triple sheet thermoforming operations should provide at least 15 watts per square inch (wsi) on each of the top and bottom oven banks, for a minimum machine total of 75 wsi. To facilitate more responsive and zoned heating, ceramic elements can be spaced to provide 30 wsi, or quartz tubes with a maximum 60 wsi can be used for each of the 5 oven banks, for a total of 300 wsi. Accordingly, it is an objective of the present invention to provide 3 top and 2 bottom heat sources having a minimum density of 15 wsi, and PLC controlled closed loop control systems facilitating multivariate oven zone and heater profile control from cycle to cycle as suggested in FIG. 18.

[0086] [[Below rigid thermoplastic member **27** is deck] Deck under carriage **406** is disposed below rigid thermoplastic member **27**. Deck under carriage **406** comprises a main, substantially flat under carriage body **436**, nine depending leg recesses **438**, four rigid member retention walls **440,** contiguous to retention walls **440** horizontal surfaces **442**, contiguous to horizontal surfaces **442** downward extending surfaces **444**, and contiguous to downward extending surfaces **444** a horizontal margin **446**[, said horizontal]. Horizontal margin **446** is [being] substantially coincident in the vertical plane to [the] horizontal margin **416** formed in deck surface **414**. In more detail, deck under carriage **406** further comprises reinforcing webs **448**, fork tine deflector details **450**, and centrally located, four upward extending bosses **452** forming central select fusing surfaces **454**. It may also be seen that outside border [boarder] **456** [characterized by the plurality of] includes downward extending surfaces **444** of deck under carriage **406**, which cooperate and are compression molded against the eight perpendicular corner walls **418**, the four [4] perpendicular inner walls **422,** and the remaining margin **416** comprising flat deck surface **414.** Also understood in the formation of the four retention walls **440** is holding space **441** for rigid member **27.**]]

[0075.1] Another object of the invention are controls suitable for emitting higher or lower heat profiles from one frame carrying thicker sheet to a next frame carrying thinner sheet. Triple sheet thermoforming apparatus features rapid response heaters and heater control so that the triple sheet article to be thermoformed according to the triple

sheet methodology can be constructed out of thermoplastic sheets comprising different fillers and thickness in cross section and in other combinations which optimize the strength to weight to cost ratios of the article being constructed. For example, in the case of article **200**, top sheet **25c** can be thinner in cross section than sheets **25a** or **25b**, for a variety beneficial results.

[0087] [[Below deck under carriage **406** is lower] Lower pallet support structure **410** is positioned below deck under carraige **406**. It is understood that support structure **410** operates as a load distributor **470** and comprises nine upward extending leg supports **460**, twelve raised rib ramp structures **462**, four pallet jack cutouts **464**, and flat surfaces **466** generally defining an outside horizontal margin **468** and four separate inside horizontal margins **472**. As can be seen, support structure **410** is heavily detailed with a plurality of bosses, ribs, webs, gussets, retention walls, depressions, margins and the like to produce a load distributor **470** with both flexural stiffness and load pressure distribution capabilities.]

[0076.1] Now moving on to the clamp frames, it will be appreciated after reviewing the operational functions of the apparatus described in connection with FIG. 16 that programmable logic controls are required for proper operation of the clamp frames. Such precise control is not required in twin sheet apparatus. In twin sheet apparatus the first and third or second and fourth frames are simply controlled, such as by frame mounted limit switches and the like, to remain closed to carry the twin sheet article from the form station to the load/unload station at the end of the twin sheet cycle. In other words, the twin sheet frame cycle is open/close/open close at the form station. In the example of FIG. 16 first frame **14** is controlled to open for the first eleven cycles and only then remain closed to carry an article to the load/unload station in the twelfth cycle.

[0088] [[(It] Referring to FIGS. **19, 10A, 10G, and 11**, it may also be appreciated that a fifth member substantially equal to load distributing surface **308** may be thermoformed over a third mold [**47** (not shown)] residing upon the slide structure **48** affixed to upper platen **40**, such that upon the completion of the procedure characterized by FIG. **10G** [Drawing **G** of FIG. **10**], the third frame [3] **18** opens, lower platen **38** retracts, a fourth sheet is [**25e**] engaged by fourth frame [4] **20** rotates into form station **10** and is thermoformed over laterally slideable mold **47**, and article **400** is brought up by lower platen **38** to be compressed against and fused to pallet support structure **410** to produce a Quadruple sheet article **403** (not shown) in accordance with an advanced methodology to be referred to as Quadruple Sheet Thermoforming.]

[0077.1] Another aspect of the clamp frames is that practitioners may find it advantageous to utilize a method sequence requiring the first sheet to be formed upon a

mold associated with the top platen. Conventional twin sheet frame apparatus will not accommodate extraction of the formed sheet above the sheet line, as the pin bars are pivotally mounted to a fixed clamp frame section. For maximum flexibility the triple sheet clamp frame apparatus comprises co-engaging, pivotally opposed pin bars mounted to co-acting solenoid operated cylinders that open from the top and the bottom. Twin sheet clamp frames typically open from the bottom. Although the invented apparatus can be practiced in the mode suggested in FIG. 3 with conventional twin sheet pin bar arrangements, pivotally opposed pin bars would be required to practice all of the modes contemplated in the present apparatus.

[0088] [Racking pallet **402** is thermoformed according to one embodiment of the triple sheet methodology into a single article **400** comprised of four thermoplastic members. The four thermoplastic members are permanently fused together according to the heating, forming, fusing and cooling methods and apparatus proposed in the present invented triple sheet thermoforming machine **2**. Accordingly, it will be understood that triple sheet article **400** demonstrates some of the unique and novel features, objects and advantages that the triple sheet thermoforming methods and apparatus invented and proposed herein have to advance the art in the end market application to which the invention is applied. Racking pallets represented in the prior art, which are characteristically constructed of two or more separately thermoformed twin sheet structures that are in practice joined by mechanical fasteners, can be advantageously thermoformed into a single structure in one part production cycle of the triple sheet methodology. Thus, the mechanical fasteners and the optional plurality of separate leg supports required to maintain an upper load supporting deck and a lower load distributor in fixed and spaced parallel relation characteristic of the prior art can be eliminated altogether to significant advantage. Further, by encapsulating a rigid thermoplastic member within an enveloping structure formed by two thermoplastic sheets that are permanently fused to a thermoplastic load distributor, it will be understood that the disadvantages characteristic of the prior art, in respect to non-thermoplastic reinforcing members and mechanical fasteners, will be overcome to produce a lightweight, low cost, structurally rigid and 100% recyclable racking pallet that can be reprocessed without knock down or other added costs. Accordingly, it is seen that the triple sheet methods and apparatus disclosed herein provide a significant leap forward in the art to which the invention is applied.**]**

[0078.1] Another aspect involving the frames is the manner in which they are controlled in the "run-off" area of the sheet. As is well understood in the twin sheet methodology, the single action solenoid operated cylinders open from the bottom after the first sheet is molded and remain closed after the second sheet is molded, so that the

clamp frame can carry the twin sheet article to the load/unload station. This open/close/open/close sequence is repeated in phase in the prior art twin sheet methodology, and as mentioned, requires relatively simple process control. The triple sheet methodology is substantially more complicated. The first and third mold of the method sequence of FIG. 3 must stroke though the sheet line a distance that accommodates the path traveled by the opening pin bars. The second mold in the method sequence only forms a seal to minimize the need for stroke through. This arrangement will be better understood by referring to FIG. 3G in particular, which shows the relative stroke through relationships of the three sheets of the article **200.**

[0090] [It is intended in the triple sheet method that the procedures of molding the envelope, adding the rigid insert and compressing the three members between the two platens occurs in fast succession and while the heated molded thermoplastic sheets retain their ability to achieve interfacial contact and fusion through the principle of hot tack adhesion, which in the case of crystalline polymeric materials such as HDPE occurs about 5 –10°C above the temperature at which the polymer transitions into a glassy or fusible state. If the rigid structure is unable to adhere and fuse to the heat molded thermoplastic used, it would be feasible to pre-treat the rigid thermoplastic structure with an application of auxiliary heat, or the dispensing application of a molten low density PE with a relatively high melt index and lower density, which would act as a fusing media therebetween.]

[0079.1] Turning now to the triple sheet platen control apparatus, it will be understood, particularly in light of the aspect of pin bar travel, that the platens travel from and to a plurality to different open and closed positions during each cycle of the apparatus. This is in contrast to twin sheet apparatus wherein the lower platen has an open position and two closed positions, the first closed position relative thermoforming the first sheet and the second closed position relative the compression phase, while the upper platen has one open position and one closed position, the close position concurrently relative thermoforming the second sheet and the compression phase.

[0091] [Referring now to FIGS. **16A-G** [Fig. **16**], an alternative processing sequence producing triple sheet article **400** (see FIG. 11) is shown in [Drawings **A through G**]. [Triple] This sheet article **[400a]** is substantially equal to the prior triple sheet article **400**. The principle difference of interest is that rigidizing structure **27** is encapsulated within an envelope of plastic formed by sheets **25a** and **25c** during the triple sheet thermoforming procedure demonstrated in the later equivalent [Drawings **D and F** of FIG **10]** FIGS. **10D** and **F**. Although the positioning of structure **27** may be accomplished by manual, semi-automatic or automatic means as preferred by

the practitioner of the triple sheet methodology, and may be constructed of wood, metal or any other material as may also be preferred and intended to impart strength and improved physical properties, it will be understood that such a sequence has problems.]

[0080.1] In triple sheet apparatus, the lower platen has at least one open position, and at least three closed positions relative thermoforming one sheet of plastic and two compression phases. The upper platen has at least two open positions, with one relative the actuation of the mold shuttle system and one relative withdrawal from the sheet line. The upper platen has at least two closed positions relative a first thermoforming and compression phase and a second relative a second thermoforming and compression phase. A third closed position may also be introduced as an assist function cooperating with the thermoforming of a sheet associated with the lower platen (the technique is known as "plug assist"). Therefore, according to this requirement, a more complex system of precise controls is provided for triple sheet apparatus. The system of controls includes the addition of machine operator platen control functions and settings at the computer console **64** and increased code at the PLCs for additional control circuits to expand the functionality and respective open and close instructions phased with the precise operation of the platen apparatus.

[0092] [In FIG. **17,** an exploded sectional view of FIG. **16F** [Drawing **F** of FIG. **16]** is illustrated to provide fuller detail of the [a] proposed embodiment of a triple sheet article being selectively fused with the apparatus of the present invention to disadvantage. When triple sheets **25a, 25b** and **25c** are compressed between upper mold **46** and lower mold **42**, it is understood that some advantageous compression resistance is provided by preferred structure **27**, a thermoplastic hybrid honeycomb member expanded from a single sheet of the same material(s) used to mold the triple sheet article. However, unsupported spae **106** is located about the general region **100** of article **400** [showing a] when sheet of thermoplastic **25c** is in the closed clamp frames **104** and the compressed molds **46 and 42**[, is unsupported space **106**]. Two problems are evident in FIG. **17.**]

[0081.1] Further more, in order to facilitate the two compression phases contemplated in the operation of the apparatus, some additional intervention is required, which intervention is dependent upon the type of platen systems are deployed in the apparatus. In the one type of apparatus set forth in 3,925,140, the platens are interlocked for the compression phase by means of four rotating vertical locking shafts and lugs associated with the upper platen and lug-receiving heads adjustably mounted to threaded rods associated with the lower platen. In twin sheet apparatus, where only one

compression phase is contemplated, the lug receiving heads are manually adjusted to provide for the proper receipt of the lugs in the key-hole openings of the heads. This manual adjustment and calibration is typically a one-time set-up function. In order to facilitate the two compression phases of the triple sheet apparatus, wherein the relative closed positions of the opposed platens are different for the two compression phases, it would be necessary to actuate either the locking shaft of the upper platen or the threaded rod and receiving head of the lower platen. This intervention requires additional equipment and precise control systems for in-cycle actuation.

[0093] [[The selective] Selective fusing points **108** between sheet **25c** and sheet **25a** (shown in phantom) are unsupported [and] such that compression applied to cause the two otherwise suitably heated thermoplastics to create a thermobond will likely fail under robust operating field conditions. Secondly, the length and attitude of [the] run off portions **110** of sheet **25c**, portions **112** of sheet **25a** and portions **114** of sheet **25b**, are such that they interfere with the extending and retracting movement of the sheets upon the molds upon the platen as well as the opening and closing operations of the opposed double acting clamp cylinders **116 and 118**. Therefore, to overcome these two problems of the proposed sequence of the proposed triple sheet method represented in FIG. **16**, an auxiliary compression apparatus is contemplated.]

[0082.1] In a second type of apparatus, as set forth in 5,800,846, the selectable positions of the platens are facilitated by actuation of controllable motors and observed by linear variable displacement transducers vertically positioned adjacent the platens. When the platens are closed for the compression phase the upper and lower platens are locked in place by disk brakes and/or friction plates. Thus, it will be appreciated that the apparatus of '846 is more amenable, when additional PLC control circuit means are provided, to facilitate the two compression phases contemplated in the triple sheet apparatus, than the alternate '140 apparatus.

[0094] [As seen in FIG. **18**, an exploded sectional view of an alternative arrangement to the one shown in FIG. **17** is disclosed. [The run] Run off portions **110, 112 and 114** are directed away from the extending and retracting movement of the sheets upon the molds upon the platens. [The run] Run off portions **110, 112, and 114** are further directed away from the pivoting action of the clamp cylinders **116 and 118**. [Compression assist tooling **120** is also shown.] Compression assist tooling **120** is laterally shifted into unsupported space **106** to aid in the selected fusion through heat and pressure of sheets **25c and 25a**. In one preferred embodiment of the [present] presently invented methods and apparatus, compression assist tooling **120** comprises expanding members **122a** and **122b** that are expanded by mechanical pneumatic apparatus **124** during the procedure

characterized by [Diagram **F** of FIG. **16]** FIG. 16F. Also shown are dimensions **A, B, and C,** wherein dimension **A** equals the expanded dimension of members **122a and 122b**, dimension **B** equals the vertical distance between run off portions **112 and 114** of sheets **25a and 25b,** and dimension **C** equals the compressed dimension of members **122a and 122b** in the extend and retract mode. As will be understood, to aide in the triple sheet thermoforming of the proposed article **400a**, region **100** is engineered (or optionally the molds are thrust further through the sheet line) so that dimension **C** is equal to or less than dimension **B**, such that the compression assist tooling **120** can be laterally inserted into area **106** without interference. In cooperation with the compression of upper platen **40** and mold **46** against lower platen **38** and mold **42**, expanding members **122a and 122b** are opened to resist the compressive action of the triple sheet method. Also optionally incorporated into compression assist tooling **120**$_1$ is means **131** for introducing temperature regulated compressed air or vaporized water into the open space **126** formed between sheets **25a and 25b.** Seal plate **128** operates to preserve the seal provided with the expansion of members **122a and 122b**. Optionally, compressed air may be introduced into space **126** through a hole pierced through sheet **25b** by the operation of mold **42** in known manner. Optionally included with expanding members **122a and 122b** are heated elements **129** and RTD sensors **130** for precise temperature control. The heated elements **129** deliver heat to areas **108** to be selectively fused.**]**

[0083.1] It should also be understood that other means of platen control facilitating the two compression phases contemplated in the present apparatus are available, as would be known by referring to the associated platen control arts practiced and preferred in the numerous other plastic molding arts, such as injection and resin transfer molding apparatus, and the like. Furthermore, the hydraulic array mold support suggested in '846 may be combined with the platen locking apparatus of '140, and conversely, the pneumatically inflated air bags of '140 can be combined with the platen locking apparatus of '846 to achieve the object of facilitating two relative closed platen positions for the two compression phases of the triple sheet apparatus.

[0095] [Also understood, but not shown in FIG. **18**, are slide assemblies **132** which in the extract and extend manners portrayed in FIG. **19** operate to laterally shift compression assist tooling **120** into and away from space **106** during the production sequence represented in [Drawing **F** of FIG. **16**] FIG. 16F. It is also understood that the lateral movement of compression assist tooling **120** upon [the] slide assemblies **132** is greater than the width of the lateral dimensions in the horizontal direction of [the] double acting clamp cylinders **116 and 118** fastened to [the frames **18** of the circular wheel **12** (see FIG.1. This arrangement is preferred to prevent interference from

[the] double acting clamp cylinders **116 and 118** upon the slide assemblies **132** and compression assist tooling **120**. [(]In practice, this may mean that [the] compression assist tooling **120** will have to slide laterally 9+ inches away from mold **42a** to prevent [the] tooling **120** from interfering with second frame [2] **16** when sheet **25b** is thermoformed over lower mold **42a** in the contemplated production sequence of FIG. **16**.[)] Accordingly, it will be appreciated that the auxiliary compression assist apparatus as disclosed may be preferred to facilitate certain embodiments available to practitioners of the advanced art of triple sheet thermoforming methods, apparatus and articles. **]**

[0084.1] Now moving onto the superstructure of the machine frame of the invented apparatus, it will be helpful to refer to FIG. 20. As seen in FIG. 20, a conventional twin sheet machine frame **150** and apparatus are shown in phantom. The machine frame components and apparatus particular to triple sheet apparatus is drawn in full line detail.

[0085.1] The triple sheet apparatus machine frame structures at the load/unload station **4** involve the floor members **156** about the base of the superstructure **150** and the cross member **158**. The members **156** and **158** are operable with elements **152** and **154** of superstructure **150** to carry the load of oven **26** in a position vertically aligned in spaced parallel relation above fully indexed clamp frames (not shown) supported upon wheel **12.**

[0096] [The triple sheet apparatus proposed may be added to virtually any existing twin sheet thermoforming machine developed in the conventional Geneva rotary machine style in which [the] wheel **12** is repeatedly indexed in +/- 90° increments after a predetermined dwell time. The triple sheet apparatus included in a proposed embodiment of a triple sheet apparatus retro-fit kit is listed hereunder, and includes the following elements, as shown in FIGS. **1, 18 and 20**: an upper load/unload station preheat oven **26** and supporting frame members **156** and **158;** co-engaging, pivotally opposed pin bars mounted to co-acting solenoid operated cylinders **116** and **118** and four subclamp-frame assemblies **14a, 16a, 18a** and **20a**; a laterally movable slide assembly **48** adapted for mechanical cooperation with platen **40** and form station supporting frame members; all associated pneumatic, hydraulic and electric motors, drives, switches, relays and other mechanical or electromechanical devices and instruments; and, all digitally controllable processors plus programming suitable for the practice, methods and apparatus of the triple sheet thermoforming invention. FIG. **20** is provided to illustrate the triple sheet apparatus and elements thereof, that are [is] added to a conventional four station rotary twin sheet thermoformer of type referenced above. **]**

[0086.1] In the regions of the form station **10** are a plurality of structural members **160** generally extending to the left and right of columnar elements **151** defining

the form station **10**. The structural members **160** are adapted to support the combined loads of the laterally movable mold shuttle system **48** and the thermoforming molds (not shown) attached thereto. As will be described below in more detail, mold shuttle system **48** operates to shift a first mold **44** laterally into position into the form station **10** to be engaged by the vertically movable platen **40** to thermoform a sheet of thermoplastic over said mold **44**, and then to shift a second mold **46** laterally into position in the form station **10** to be engaged by the vertically movable platen **40** to thermoform a successive sheet of thermoplastic over second mold **46.** Thus, mold shuttle system **48** reciprocates two molds back and forth into and out of the form station **10** in phase with the triple sheet thermoforming methodology.

[0097] [As can be further seen in FIG. **20**, existing twin sheet thermoformer **2a** is shown in phantom. In particular, to simplify the drawing, only thermoformer superstructure **150,** ovens **28, 30, 32** and **34**, upper and lower platens **40** and **38**, load table **24**, and wheel **12** are shown in phantom. Together, these said elements define the first unload/load station **4**, the second pre-heat oven station **6**, the third final heat oven station **8** and the fourth forming station **10,** all characteristic of said twin sheet thermoformers **2a**. Apparatus added to convert an amenable twin sheet thermoformer **2a** to a triple sheet thermoformer **2b** is drawn in full line detail.]

[0087.1] It is also understood that several variations of the apparatus relating to the mold shuttle system **48** exist. For example, in place of one mold there may be equipment to provide a pressure forming function, as described in co-pending Provisional Application Serial No. 60/241,668, filed 10/20/2000, which is incorporated herein by such reference. A plug assist function, as would be understood and anticipated by referring to application serial no. '668 could also be used, in which case plug assist tooling would replace one of the contemplated molds **44** or **46**.

[0098] [In particular, the original superstructure **150** extending to support wheel **12** and to define the unload/load station **4** includes two pillars **152** and two beams **154** in the twin sheet methodology. The columns and beams **152** and **154** are reinforced by floor members **156** about the base of the superstructure **150** and by cross member(s) **158** such that the members **156** and **158** are operable with elements **152** and **154** of superstructure **150** to carry the load of oven **26** in a position vertically aligned in spaced parallel relation above fully indexed clamp frames (not shown) supported upon wheel **12.** Also added in the triple sheet methodology to superstructure **150** of the twin sheet apparatus about the form station **10** are a plurality of structural members **160** generally extending to the left and right of elements of superstructure **150** defining the form station **10**. The triple sheet structural members **160** are adapted to support the combined loads of elements of the

laterally movable mold slide apparatus **48** and the thermoforming molds (not shown) attached thereto. As will be appreciated, slide apparatus **48** operates to shift a first mold **44** laterally into position in the form station **10** to be engaged by the vertically movable platen **40** to thermoform a first sheet of thermoplastic over said mold **44**, and then to shift a second mold **46** laterally into position in the form station **10** to be engaged by the vertically movable platen **40** to thermoform a third sheet of thermoplastic over second mold **46.** Thus, slide apparatus **48** reciprocates two or more molds back and forth into and out of the form station **10** in phase with the triple sheet thermoforming methodology. It is also understood that further variations of the apparatus relating to the mold slide **48** exist. For example, the slide structure may be contained within the vertical margin defined by the borders of the vertically moveable platen, such that approximately 1/3 or less of the platen is developed to thermoform triple sheet articles (This option is shown in FIG. **1**). In such cases, structural members **160** would not be contemplated as part of the triple sheet apparatus retrofit kit. Also, it is understood that the slide apparatus **48** may be movable according to, but not limited to, hydraulic or pneumatic rams, mechanical drives or electric motor assemblies as are well know and as may be preferred by the practitioner of triple sheet methods and apparatus. **]**

[0088.1] It should also be understood that a mold shuttle system **48** in another embodiment of the invention may be contained entirely within the vertical margin defined by the borders of a vertically moveable platen, such that approximately 1/3 or less of the platen would be developed to thermoform a triple sheet article. In such cases, structural members **160** adjacent to the right and left of the form station **10** would not be contemplated as part of the triple sheet apparatus. It is also known that thermoforming machines come in many sizes. As may be seen in FIGS. 21A and 21B, machine platens characteristic of the heavy gauge sector of the thermoforming industry range up to 180 inches in width (transverse direction of sheet extrusion) and 360 inches in length (extrusion direction). Accordingly, it may be understood that laterally moving slide structures **49** can be arranged to slide successive molds contemplated in the triple sheet methodology in the transverse (see 21A) or extrusion (see 21B) directions upon a platen. It may also be understood that if the platen is sufficiently large, two or more articles, such as polymeric dumpster lids or fuel tanks, may be thermoformed simultaneously with co-acting shuttle systems **48a** and **48b**. As may be appreciated in reference to FIG. 21A, wherein the production of long articles, such as a kayak is proposed, the limiting factor in the size of a product that can be made according to the present embodiment of triple sheet thermoforming apparatus is determined by the size of the machine platen **40**.

[0099] [It is further recognized that thermoforming machinery of the type referred to above comes in many sizes, in respect to the platens. As may be seen by the Drawings **A and B** of FIG. **21**, existing machine platens characteristic of the heavy gauge sector of the thermoforming industry range up to 180 inches in width (transverse direction of sheet extrusion) and 360 inches in length (extrusion direction). Accordingly, it may be understood that laterally moving slide structures can be arranged to slide successive molds contemplated in the triple sheet methodology in the transverse (see Diagram **A)** or extrusion (see Diagram **B**) directions of a platen. It may also be understood that if the existing platen is sufficiently large, two or more articles, such as dumpster lids, may be thermoformed simultaneously with co-acting slide structures **48a** and **48b**. It may be advantageous to attach upon the superstructure enclosing the form station of any such thermoforming machine certain out riggings **160** suspending outer elements of a slide structure operable with inner elements of a slide structure to facilitate the lateral shifting two or more molds into or away from mold engaging means mounted upon a vertically movable platen. Indeed, this arrangement is preferred in triple sheet thermoforming machines dedicated to the constant long term production of articles of a uniform character, such as reinforced triple sheet article racking pallet **402.** As may be appreciated in reference to FIG. **21**, wherein the production of long articles, such as a kayak is proposed, the limiting factor in the size of a product that can be made according to the methods of triple sheet thermoforming is determined by the size of the twin sheet machine platens.]

[0089.1] In the preferred embodiment of the apparatus it is advantageous to attach upon the conventional superstructure **151** enclosing the form station column and beam structures **160** suspending outer elements of the mold shuttle system **48** operable with inner elements of the mold shuttle system to facilitate the lateral shifting of two molds into or away from mold engaging means **185** mounted upon a vertically movable platen **40**. In this arrangement the full area of the platen **40** may be developed for supporting the mold(s) used in the apparatus.

[0100] [Also included in the triple sheet apparatus retro-fit kit proposed to convert a twin sheet machine to the triple sheet methodology are new clamp frame sub-assemblies **104** comprising opposed double acting clamp cylinders **116** and **118** to which are attached opposed pin bars **117** and **119.** As is described in some detail above, the clamp frame sub-assemblies **104** are distinguished by their ability to pivot out of way of the upward path traveled by sheets **25a** upon molds **44** and **44a** attached to upper platen **40** as proposed in one or more of the preferred embodiments of the present invention.]

[0090.1] In further elaboration of the mold slide system **48** and its basic constituent parts, it will be understood in conjunction with FIGS. 22A and 22B, that the mold shuttle system **48** is characterized by three zones including zone **170** occupying a position between the load/unload station **4** and the form station **10**, zone **172** occupying a position between the third oven station **8** and the form station **10**, **and** zone **174** co-existing with the upper platen **40** within the form station **10**. Zones **170** and **172** are supported by the machine frame elements **160** that are attached to superstructure **151**. Within zones **170**, **172** and **174** is track **179**, or the equivalent, comprising track sections **180**, **178** and **176**, respectively. Track section **176** is attached to the upper platen **40**, which platen travels vertically from open to closed positions. Mounted upon the track **179** are two moving platforms **182** and **184**, upon which molds **46** and **44**, or alternate tooling are affixed, respectively. The platforms **182** and **184** selectively travel laterally into and out of the form station **10** by controlled actuation of the shuttle system. Upon entry into zone **174** a platform is mechanically engaged by rigid clamping means **185** mounted upon the platen for movement of the platen from open positions to closed positions. It may also understood that although the shuttle system **48** and frame elements **160** are orientated in a side-to-side direction, the shuttle system could be rotated 90 degrees in a front-to-back direction in relation to the platen as preferred by the practitioner or the machine builder of the apparatus.

[0091.1] Accordingly, it will be appreciated that in synchronization with the triple sheet methodology mold slide system **48** is operable to move platform **182** and mold **46** into form station **10** to be releaseably engaged by traveling platen **40** to thermoform a first sheet and to replace platform **182** with platform **184** and mold **44** into the form station **10** to be releasably engaged by traveling platen **40** to thermoform a second sheet. The reciprocating action performed by mold shuttle system **48** may be provided by precise controllable means including hydraulic, pneumatic or electromechanical actuation, or combinations thereof, as known in the actuation arts or as may be preferred by the practitioner of the triple sheet methodology or the machine builder of the triple sheet apparatus. Furthermore, although a reciprocating shuttle system **48** is suggested, the molds **44** and **46** could be independently pushed into and pulled from the platen engagement position **177** from zones **172** and **170** along track like apparatus **179** by controllable ram means **181**, as suggested in FIG. 23. Accordingly, it is to be understood

that a mold shuttle system delivering two molds to the form station from relative movement therefrom for thermoforming two sheets can be accomplished by various means, and all such means fall within the scope of the invented triple sheet thermoforming apparatus.

[0101] [In further elaboration of the slide structure **48** and its basic constituent parts, it will be understood in conjunction with FIGS. **20** and **22A** and **22B**, that the slide structure **48** is characterized by three zones including zone **170** occupying a position between the load/unload station **4** and the form station **10**, zone **172** occupying a position between the third oven station **8** and the form station **10** and zone **174**, co-existing with the upper platen **40** within the form station **10**. Zones **170** and **172** are supported by the frame elements **160** that are attached to superstructure **150**. Within zones **170, 172** and **174** is track **179** comprising track sections **180**, **178** and **176**, respectively. Track section **176** is attached to upper platen **40** which travels vertically from open to closed positions. Mounted upon the track **179** are two moving platforms **182** and **184** which travel laterally into and out of the form station **10**. Upon said platforms of the present embodiment are thermoforming molds **44** and **46**. It may also understood that the slide structure **48** and frame elements **160** may be re-orientated from the extrusion direction of the platen to the traverse direction of the platen as would be intended for other article(s) to be thermoformed according to the triple sheet methodology. Further, it would be understood that the constituent parts of the slide apparatus **48** could be contained entirely upon the working surface of upper platen **40** and within the border **41** defined by the vertical path traveled by the platen **40** traveling from an open position to a closed position.]

[0092.1] Referring finally to FIG. 24, a plan view of an automated work cell **250** comprising the invented apparatus and auxiliary equipment is shown. In order to facilitate the loading and unloading function according to CYCLE 7 **252** of FIG. 16, an automated sheet delivery system **254** is provided. As suggested in reference to article **200**, two types of plastic sheet **25i** and **25ii** are used. The sheet delivery carriage **256** selects the desired sheet to be charged into the apparatus. The successive sheets of plastic are then conveyed through three controllable ovens **258, 260** and **262** in the desired order. The heated sheets enter the form station **10** where they are thermoformed in the desired sequence between the opposed platens **40** and **38**. As suggested in reference to article **300**, after the first sheet is thermoformed and extracted from the sheet line by movement of platen **38**, rigidifying structures **72** are introduced by means of apparatus **74** positioned externally and adjacent the form station. The apparatus **74** comprises a delivery shuttle **264** that traverses from the a position intermediate the platen to a position **266** relative a sub-assembly track system **268** comprising a three segment track **270** supporting the

structures **72i** and **72ii** that are to be sequentially encapsulated between the three sheets forming the unitary article. The delivery shuttle is actuated to travel upon a shuttle track **272** for relative movement. Associated with the upper platen is a mold shuttle system **48**, which is operable to position two-up mold groups **44i/44ii** and **46i/46ii** into position upon the platen for movement to positions relative thermoforming and compression phases thereafter. After the first sheet is thermoformed the second and third sheets are thermoformed and compressed together in the manners suggested in connection with FIG. 3. Once all three sheets have thermoformed and compressed together to form the pair of triple sheet articles, the wheel is indexed forward to deliver the articles from the form station to the load/unload station, where at the articles are discharged from the machine to a track system **274** that conveys the articles to a cooling station **276**, where the articles dwell for a cooling period. Thereafter, the articles are conveyed into a CNC trim station **278** where the finished articles are finally trimmed into individual units from the sheets thermoformed in a unitary sub-assembly by the apparatus. Therefore, one will immediately understand that the apparatus of the present invention can be deployed in combination with auxiliary equipment and apparatus to provide fully automated work cells in which the only labor contemplated is associated with charging the auxiliary apparatus with raw materials, article inserts and removing the recyclable by-product from the CNC trim station.

[0102] [Accordingly, it will be appreciated that in synchronization with the triple sheet methodology that slide apparatus **48** is operable to move platform **182** and mold **46** into form station **10** to be releasably engaged by traveling platen **40** to thermoform a first sheet and to move platform **184** and mold **44** into form station **10** to be releasably engaged by traveling platen **40** to thermoform a second sheet. The reciprocating action performed by slide apparatus **48** may be provided by means including hydraulic or pneumatic actuation, electromechanical apparatus, or a combination thereof, as is preferred by the practitioner of the triple sheet methodology or the machine builder supplying the triple sheet apparatus.]

[0093.1] Thus it maybe seen that the triple sheet apparatus, together with the microprocessor programmable and menu-driven control capabilities, offers a wider degree of flexibility in process functionality and adaptability. Heat control of the triple sheet apparatus will be in accordance with algorithms that adjust heat profiles within the five ovens in response to sensor inputs concerning air temperature, component temperatures and the sagging catenary disposition of the successive thermoplastic sheets engaged in

the clamp frame apparatus of the invention. The heat control algorithms may be over-ridden by manual adjustment by a skilled operator as required, or again, preferably controlled by adaptive algorithms that increase or decrease heater output in accordance with the forming, fusing and cooling sequences and dwell times of the preferred triple sheet apparatus. Precise apparatus controls with respect to the sequential operation of the platens, the forging-like actuation of the compression phases and the sequential control of the mold shuttle systems are provided to facilitate automated functionality of the invented form station apparatus. The object of thermoforming triple sheet articles by simultaneously heating three successive sheets in three controllable ovens, thermoforming the three heat deformable sheets over three shape-giving molds, and then compressing and instantly fusing the three shaped sheets together between selectively controlled opposing platens is achieved and provided in the invented apparatus.

[0103] [In another embodiment of triple sheet thermoforming machine **2a**, wherein the triple sheet elements **26, 156** and **158** are added to the first load/unload station **4**, the first upper oven **26** includes means to adjust the vertical position of the oven **26** above and relative to the wheel **12** carrying articles forward from the fourth form station **10** to be unloaded. As will be appreciated, articles thermoformed against molding surfaces that extend well above the vertical plane defined by the wheel **12** will crash into the sheet metal **35** enclosing the first upper oven **26.** Accordingly, this potential problem is addressed with the addition of controls that instruct the oven to travel vertically from a closed position to an open position before the wheel **12** is indexed forward carrying an article to the load/unload station **4**. The means developed to achieve this function would be substantially equivalent to the means of known character which allow the lower ovens **30** and **34** to travel from an closed to an open position a fixed distance from the thermoplastic sheet in relation to its catenary displacement.]

[0094.1] It is to be understood that the drawings and descriptive matter are in all cases to be interpreted as merely illustrative of the principles, methods and apparatus of the invention. The examples and descriptions provided are not meant to be limiting the same in any way, since it is contemplated that various changes may be made in various elements to achieve like results without departing from the spirit of the invention or the scope of the appended claims.

[0105] [Referring now to FIGS. **23**, alternatives to triple sheet article **402** is proposed and described. Triple sheet article **403**, formed in the manner shown in FIG. **10**, is comprised of sheets **25a, 25c and 25d**. As can be seen, sheet **25d** is thicker in cross-section than sheets **25a** and **25c**.

Thicker sheet **25d** is proposed to increase the weight to strength ratio of proposed triple sheet article **403**. It will be understood that any of the three sheets **25a, 25c** or **25d** can be provided with a thicker or thinner thickness in cross-section, depending upon the physical requirements of the triple sheet article proposed. It is further understood that select heat profile algorithms suitable for applying heat to the preferred sheet in the cycle times proposed in the triple sheet methodology are a feature characteristic of the present invention.]

[0106] [Sheet **25d**, in addition to being thicker, can also be constructed out of a composite of thermoplastic materials, or with fillers such as glass or talc, or with resins that have narrower molecular weight distribution or higher molecular weights, such that sheet **25d** has improved physical properties (impact resistance, hardness, flexural stiffness, dimensional stability, etc.), or reduced cost. Thus it maybe seen that the triple sheet methodology and apparatus, together with the microprocessor programmable and menu-driven control capabilities preferred provide a wider degree of flexibility in process control than is characteristic of conventional twin sheet thermoforming machines. Preferably, the heat control of the triple sheet methodology will be in accordance with algorithms which adjusts heat profiles within the five ovens in response to sensor inputs concerning air temperature, component temperatures and the sagging catenary disposition of the successive thermoplastic sheets engaged in the clamp frames. The control algorithms may be over-ridden by manual adjustment by a skilled operator as required, or again, preferably controlled by adaptive algorithms which increase or decrease heater output in accordance with the forming, fusing and cooling sequences and dwell times of the preferred triple sheet methodology.]

[0107] [It is to be understood that the drawings and descriptive matter are in all cases to be interpreted as merely illustrative of the principles, methods and apparatus of the invention, rather than as limiting the same in any way, since it is contemplated that various changes may be made in various elements to achieve like results without departing from the spirit of the invention or the scope of the appended claims.]

ABSTRACT

[0108] [A pallet constructed of three sheet of moldable thermoplastic material fused together according to the triple sheet thermoforming methodology is disclosed. The pallet includes a load-bearing platform supported by a plurality of legs which depend downward to suspend the platform above the surface upon which the pallet rests. The legs form upwardly opening pockets and are molded from portions of each of the three sheets to provide compression resistance and impact strength. The top sheet of material forms the surface of the load-bearing platform and can be flat and uninterrupted between the leg pockets to support a load thereon. The middle sheet is provided to reinforce the load-bearing platform and includes a plurality of elements that extend in a first direction to fuse to the top sheet and in a second direction to fuse to the bottom sheet. The middle sheet maintains the top and bottom sheets in fixed parallel spaced apart relation. Elements of the middle sheet also extend outwardly to fuse against the inside perimeter surfaces formed by the top and bottom sheets to provide toughness and flexural strength around the pallet boarder. The bottom sheet of material is formed with raised ribs which traverse the distance between elements of the middle sheet to increase the flexural strength of load-bearing platform. The invention is characterized as being more rigid and impact resistant than all plastic twin sheet pallets and is 100% recyclable.]

[0095.1] A thermoforming machine for manufacturing triple sheet thermoplastic articles is disclosed. *The thermoforming machine comprises three controllable ovens for* heating three sheets to a heat deformable temperature, three shape giving molds for separately thermoforming each sheet in succession, and forging-like means to compress the three thermoformed sheets into a unitary article. The three sheets are thermoformed *and compressed together in a form station comprising upper and lower platens.* Acting with the upper platen is a mold shuttle system for moving two of three molds into position relative the thermoforming and forging-like operations of the apparatus.